

**The Application of a Land Information System
to
Land Readjustment
for
City Planning in Thailand**

Thesis presented in partial fulfilment of the requirements of
the University of Edinburgh
for the degree of Doctor of Philosophy (Ph. D.)

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1995



DECLARATION

I declare this thesis represents my own work and that where the work of others has been used it has been duly accredited.

Mr Dusdi Chanlikit

1 June 1995

To those who have fulfilled my life with encouragement and love -

My father, Suchart;
My wife, Hansa
My daughters, Wanthida and Supak

In loving memory of my beloved mother, Sungvien

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PUBLICATIONS

The following papers have been published as a result of the findings of this research.

1. CHANLIKIT, D. and KIRBY, R. P., 1993. The Use of Photogrammetric and GPS techniques for Digital Mapping of Land Readjustment in Thailand. *Proceedings AUSIA '93': Advances in Urban Spatial Information and Analysis* (eds. D. Du, J. Chen, B. Forster and X. Shi). Press of Wuhan Technical University of Surveying and Mapping, Wuhan, P.R. China. 292 pages: 84-93.
2. CHANLIKIT, D., 1995. Urban and Suburban Mapping with the AP190 Analytical Plotter. *Photogrammetric Record*, 15(85): 51-55.

Copies of these publications are bound at the rear part of this thesis.

ABSTRACT

The current population of Bangkok, Thailand, of over 6.5 million places this city among the largest in the Developing World. Recent economic expansion has been rapid, bringing with it pressures on urban land use and a concurrent rapid rise in market land prices which outstrip income and productivity growth. Urban land readjustment has been considered to provide a potentially significant solution to the availability of urban land in Bangkok and the provincial cities of Thailand.

A land information system (LIS) has been employed in the context of land readjustment in the urban and suburban environments of Bangkok. The LIS has involved field surveying, photogrammetry and geographical information system packages (ARC/INFO, TIN and AML), the output being a spatial and aspatial database and maps in a variety of forms. Previously an information system has not been used for urban land readjustment. Also cadastral maps, which are regarded as a rudimentary requirement for city planners, are currently produced by slow and labour intensive field survey methods. Consequently an alternative scheme involving up-to-date large scale aerial photographs has been developed, with the help of ground control by a global positioning system (Trimble 4000ST GPS), an analytical stereoplotter (AP190), and an independent model block adjustment program (BLOKK). It is evident that this photogrammetric approach requires less effort than conventional field survey methods. An additional result is a model for urban land readjustment (MULAR) which has been developed for editing and analysing data.

Two different areas in the Bangkok Metropolis have been used as experimental areas for the application of the MULAR system. In the urbanised area, Klong Toei district, the system has been utilised to manage the land readjustment approach where urban utilities (eg road, electricity, telephone, water supply, drainage system) are due to be provided to the new readjusted area. In the suburban area, Lad Krabang district, the system can be used interactively for city planners where both urban utilities and urban facilities (eg school, playground, park) are still being planned for the new environment. The MULAR system permits the city planners to interact with the graphic data and also provides non-graphic data relating to land ownership within the study areas. The MULAR system is proposed in this thesis as an efficient tool to tackle some of the problems that face city planners in Thailand today.

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ABBREVIATIONS AND ACRONYMS

AAT	= Arc Attribute Table
AIT	= Asian Institute of Technology
AML	= Arc Macro Language
BLIS	= Bangkok Land Information System
BMA	= Bangkok Metropolitan Administration
BMULRC	= Bangkok Metropolitan Urban Land Readjustment Committee
CPB	= City Planning Bureau
CU	= Chulalongkorn University
DBMS	= Database Management System
DEC	= Digital Equipment Corporation
DLD	= Department of Land Development
DMR	= Department of Mineral Resources
DOE	= Department of the Environment
DOL	= Department of Lands
DTCP	= Department of Town and Country Planning
E-R	= Entity-relationship
ESCAP	= United Nations Economic and Social Commission for Asia and the Pacific
ESRI	= Environmental Systems Research Institute
FIG	= International Federation of Surveyors
GEOVAX	= Department of Geography, VAX Computer System
GIS	= Geographical Information Systems
GPS	= Global Positioning System
GUI	= Graphic User Interface
IAP	= Interactive Application Processor
IT	= Information Technology
JICA	= Japan International Cooperation Agency
LIS	= Land Information Systems
LIS/GIS	= Land and Geographic Information Systems
MAC	= Ministry of Agriculture and Co-operatives
MEA	= Metropolitan Electricity Authority
MGE	= Modular GIS Environment
MOI	= Ministry of Interior
MULAR	= Model for Urban Land Readjustment
MWA	= Metropolitan Waterworks Authority
NESDB	= Office of the National Economic and Social Development Board
NF	= Normal Form
NHA	= National Housing Authority
NIDA	= National Institute of Development Administration
NSO	= National Statistical Office
NULRC	= National Urban Land Readjustment Committee

PAT	= Point/Polygon Attribute Table
PLRC	= Provincial Land Readjustment Committee
RDBMS	= Relational Database Management System
RTSD	= Royal Thai Survey Department
SOFIE	= Study of Options for Financing Infrastructure Expansion
SIS	= Spatial Information Systems
SQL	= Structured Query Language
TIN	= Triangulated Irregular Network
TOT	= Telephone Organisation of Thailand
UN	= United Nations
UNF	= Unnormalised Form
VMS	= Virtual Memory System

Note:

Thai units

U.K. units

40 Baht	= 1 Pound sterling (Date: 12 April 1995)
1 rai	= 1600 square metres
1 square wah	= 4 square metres

Chapter 1

INTRODUCTION

1.1 BACKGROUND AND PROBLEMS ASSOCIATED WITH URBAN LAND READJUSTMENT IN THAILAND

As indicated by the population projection released by the Population Division of the United Nations, the world's population will increase from 5.3 billion in 1990 to 8.5 billion in 2025 (United Nations, 1993). It is also conjectured by the United Nations that the growth rate in Southeast Asian countries will be relatively high. Thailand, with a population of 54.5 million in 1990, is currently growing at an annual rate of about two per cent. The Bangkok Metropolis, the capital of Thailand, is heavily populated with approximately six million people in 1990 and a growth rate of about 3.73 per cent a year, as described by the National Statistical Office of Thailand (NSO, 1990). The NSO also discloses that the Bangkok Metropolis is not only the most densely populated city in Thailand but also the largest province in terms of the number of households. As the city expands, 50,000 new houses a year are required to cope with the demand. As a result, land planning is of paramount consideration and, in this context, urban land readjustment is considered to be one solution to the need for public accommodation.

Thailand is a mixed-economy country where most land is privately owned. The process of urban land development is particularly rapid in the Bangkok Metropolis and usually introduces a range of problems. These problems involve the inadequate and delayed provision of urban utilities and urban facilities, high land prices, and withholding of land from development. These problems directly affect not only the private sector but also the government agencies. Government bodies such as the

National Housing Authority (NHA) requires land for specific housing projects and the NHA has to follow cumbersome administrative procedures in order to acquire the land with limited financial budgets by negotiated purchase. The National Urban Land Readjustment Committee (NULRC) and the private sector have both found that current procedures and available technology are insufficient to cope with the existing common problems concerning urban land readjustment which is fully defined in chapter 2 (section 2.5.1). These common problems are outlined as follows:

- Lack of good cadastral and large-scale base maps.
- Data related to land ownership are incomplete or unreliable, being collected manually, which leads to difficulty in retrieving and updating.
- The traditional surveying methods that are currently applied consume time, money, and manpower.
- Even though land readjustment has been applied and has attained success in many parts of the world, for example in Germany, Japan, and South Korea, it is a comparatively new concept in Thailand. Several studies have been launched by government agencies at the feasibility level since 1988 (eg NHA) in order to unite fragmented and scattered landholdings into single units for better planning, servicing, and subdivision by means of urban land readjustment. As an indication of this, the NULRC has recently been set up.

1.2 AIM OF THE RESEARCH

The aim is to improve the land readjustment mechanism for Thai authorities, by introducing a more technical and computer-based system, which would be faster to implement. In consequence, the principal aim of this research is:

- **to design and develop a common strategy for an urban land readjustment system in Thailand by means of a Land Information System (LIS).**

1.3 OBJECTIVES OF THE RESEARCH

The study arose from a recognised need for better solutions to solve land readjustment problems. Thus, the objectives of the research are:

- to investigate the suitability of using the global positioning system (GPS), and photogrammetric techniques for building a LIS;
- to design an efficient menu interface for an effective model for urban land readjustment which is labelled MULAR;
- to investigate how an external relational database management system (RDBMS) can be utilised to strengthen the newly designed MULAR system;
- to investigate the practical and suitability of using the LIS and the MULAR system to show the benefits of an integrated solution to urban land readjustment.

To determine and illustrate how Land and Geographic Information Systems (LIS/GIS) can play a significant role in the proposed land readjustment procedure, two study areas in urban and suburban environment were chosen within Bangkok Metropolis: respectively Klong Toei and Lad Krabang districts. These two districts have very different land characteristics and by considering the practical problems associated with land readjustment in each district, the LIS could be shown to be effective.

1.4 STRUCTURE OF THE THESIS

This thesis is presented in seven chapters.

Chapter 1 sets out the background and rationale for the research project, develops a statement of the problem and attempts to identify concisely the principal aim and research objectives. It concludes by providing this brief outline structure of the thesis.

Chapter 2 outlines the growth of urban population at global scale. It includes a brief consideration of urban population growth in Southeast Asia and highlights the historical details and problems of urban land development in Bangkok Metropolis. It presents definitions of land readjustment from various views and brings together the characteristics of land readjustment. It describes the potential benefits of land readjustment to landowners and government agencies. The existing state of land readjustment as conducted in other countries is also detailed while the final part of the chapter explores the current state of land readjustment in Thailand.

Chapter 3 describes possible conditions for the successful application of land readjustment in Thailand and reports on current laws. It deals with the potential of landowners for supporting urban land readjustment and reviews currently available techniques. The drawback of existing techniques is also documented, and a new schedule for urban land readjustment in Bangkok is proposed.

Chapter 4 shows that there is wide variety of graphic and non-graphic data needed for the new schedule. It defines the location of two study areas situated in urban (Klong Toei district) and suburban (Lad Krabang district) environments. The application of surveying and photogrammetric techniques for the proposed schedule is described while the results of these techniques are also illustrated. Finally, the utilisation of a flatbed digitiser is presented as a crucial method of data capture for LIS/GIS.

Chapter 5 aims to provide an overview of the database design process and investigates the current DBMS environment in various Thai government agencies. The chapter explores the standard conceptual database design and identifies a number of choices of database management system structure. It establishes the relationship of the logical database design to physical database design and indicates how elements of the current state-of-art can be applied to permit connection to the external DBMS from the ARC/INFO environment.

Chapter 6 examines the development of an interactive graphics user interface for urban land readjustment. It concentrates on making use of the Arc Macro Language (AML) in order to create an appropriate menu interface for the MULAR system. It defines several solutions for undertaking urban land readjustment in Bangkok. Moreover, it presents and discusses the results of a series of applications and designs carried out for the two study sites. The final part compares the different approaches of the NHA and the author in undertaking urban land readjustment in the Lad Krabang project.

Chapter 7 summarises the main findings and conclusions of the study and describes the advantages of the proposed strategy over the existing practice for undertaking urban land readjustment in Thailand. It addresses the overall contribution of the author in this thesis and the discussion also presents an overview and identifies opportunities for further improvement.

Chapter 2

GENERAL CONCEPT OF LAND READJUSTMENT

2.1 INTRODUCTION

In chapter 2 the general viewpoint of land readjustment is discussed. The chapter is presented in eight main parts. The first part describes the growth of urban population in the global scale. The second part outlines urban population growth in Southeast Asia together with historical and background details of urban development in Bangkok Metropolis, Thailand. The third part deals with problems of urban land development in Bangkok. The fourth part outlines the definitions of land readjustment from various academic points of view. The fifth part investigates the characteristics of land readjustment while the potential benefits of land readjustment for landowners and the government are reviewed in the sixth part. The seventh explores the existing state of land readjustment which is being undertaken in many parts of the world. The final part shows the current state of land readjustment in Thailand.

2.2 URBAN POPULATION GROWTH IN THE WORLD

In 1798 the English economist Thomas Malthus, in his '*Essay on the Principle of Population*', launched an argument that population growth would confine itself because the food supplies are finite. He went on to argue that if population growth outran this critical level, the lack of food would bring about famine, war and human misery, then reducing the population to some sort of equilibrium level. He also mentioned that other catastrophes, such as plagues and diseases, would further limit population size.

In 1830, the world population was about one billion (1,000 million); by 1930 it was two billion, by 1975, four billion and in 1990, approximately five billion (Lowe and Bowlby, 1992). According to the population projection launched by the Population Division of the United Nations, world population will grow in the next three decades from 5.3 billion in 1990 to 8.5 billion in 2025, double the 1975 level. Since the

eighteenth century, world population has increased eight-fold and the average life expectancy has doubled. The relatively slow growth will occur in the developed countries, from 1.2 billion to 1.4 billion over the same period, while the major growth is anticipated to occur in the developing world, from 4.1 billion to 7.1 billion (United Nations, 1993), as shown in Figure 2.1. In other words, the developing countries are still growing rapidly while the developed countries have more or less stabilised.

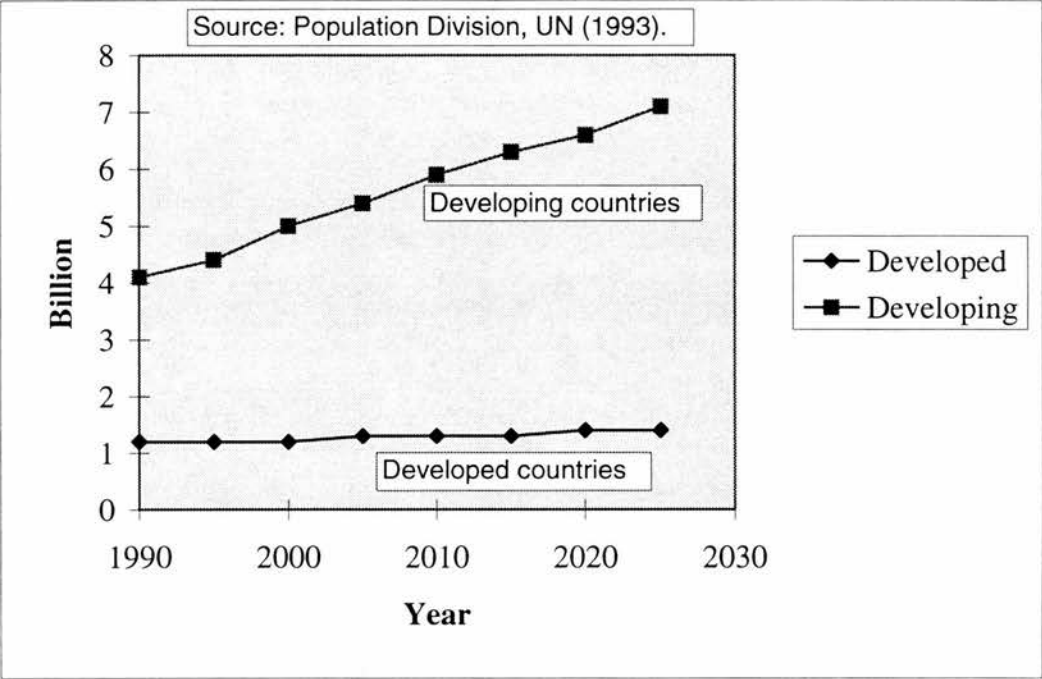


Figure 2.1 The world population growth during 1990 - 2025 A.D.

In many cases, such as in many of the developing countries of Latin America and East Asia, it is conjectured by the United Nations that the growth of population will stabilise by 2025 - 2050 while the population in South Asia and Africa is not expected to stabilise during the same period. Even though there are significant variations between countries in the developing world, population growth is occurring because death rates have fallen to 9 - 19 per thousand per annum while birth rates have stayed at around 35 - 47 per thousand. Life expectancy in the developing world has improved during this century (now between 54 and 66 years), but is still well below the figures for the industrialised world.

In many parts of the world, more of the agricultural land has degraded into desert, and where land is still farmed the land prices have soared so that people have been driven from the countryside to large urban centres (Pickering and Owen, 1994). Under these circumstances, the developed and developing countries are facing different types of urban problems. In developed countries, the problem is focused on how to keep the former city dwellers living in the city centres instead of letting them migrate into the suburban areas while the major concerns in developing countries are how to cope with rapid urbanisation. Urbanisation is a vivid phenomenon of the twentieth century. The best example of urban sprawl is Mexico City which holds a population of about 19.4 million, and is estimated to reach 24.4 million in the early part of the next century. Despite the overcrowding and bad living conditions, people still flock to urban centres because there is considerable possibility of a job, better standards of living and health care and education opportunities. For many who migrate to the cities, these opportunities are still far beyond their reach. In a nutshell, the growth of population is not only a problem for developing countries, but will evidently have indirect results in developed countries as well.

2.3 URBAN POPULATION GROWTH IN SOUTHEAST ASIA

In most of Southeast Asia, the growth of towns is rapid because the growth of the total population is rapid. Natural increase in the towns themselves ensures their rapid growth (Jones, 1975). With respect to the United Nations projections of 1993, it is clear that the annual growth rate is relatively high in Southeast Asian countries (eg 2.6% in Cambodia, 3.1% in Laos, 2.4% in Philippines) while it is considerably lower in the western world (eg 0.42% in France, 0.32% in U.K.). Thailand, a country in Southeast Asia with a population of 54.5 million in 1990 (NSO, 1990), is now growing at a rate of less than two per cent, down from more than three per cent in the 1960s, following a successful nation-wide family-planning campaign.

2.3.1 Historical and background of Bangkok Metropolis, Thailand

The Kingdom of Thailand (Figure 2.2) is located almost equidistantly between India and China; it is a tropical country of 514,000 square kilometres (200,781 square miles) - about the same size as France. It is situated between 5 and 21° N (latitude) and 97 and 106° E (longitude) and bordered by Laos to the North, Malaysia to the

South, Cambodia to the East, and Myanmar to the West. The Kingdom can be divided into 4 geographical regions: north, northeast, central, and south, consisting of 76 administrative provinces.

Thailand was called Siam until 1939. The history of Thailand as a sovereign state goes back 750 years to the founding of the first capital, Sukhothai, in the early 13th century. This initial power base enjoyed total autonomy for little more than 100 years, but in that time national patterns were forged. The roots of today's political, religious, social and culture systems can all, to a greater or lesser degree, be traced back to this period (Hoskin, 1988). The second capital, Ayutthaya, founded in 1350, rapidly eclipsed Sukhothai and was the heart of the nation until it was sacked and razed by the Burmese in 1767. Defeat was literally catastrophic but, in a remarkable display of resilience, the Thais quickly reorganised themselves under King Taksin the Great and soon expelled the invaders. King Taksin set up a new capital, Krung Thonburi, on the west bank of the Chao Phraya River.

It was his successor, King Rama I (1782 - 1803), founder of the present Chakri dynasty, who established Bangkok as his political and military power base, on the east side of the Chao Phraya River. A crescent shaped canal, Klong Lot, was dug to form an oval moat with the river. Bangkok was later surrounded by fortifications, including another city moat, Klong Ong Ang. The new capital was well protected against invasion by the river loop from the west and by almost impenetrable swamps from the east (Tapananont, 1990). Bangkok, known to the Thais as Krung Thep (City of Angels) soon rivalled Ayutthaya in beauty. Bangkok's growth during the reigns of King Rama II (1803 - 1824) and King Rama III (1824 - 1851) proceeded slowly. Great emphasis was placed on the building of magnificent palaces and temples. Bangkok started to prosper under King Mongkut (Rama IV, 1851 - 1868), and even extended outside the wall so that, by the end of his reign, Bangkok had almost tripled in area. The long and continuing modernisation period under the reign of King Piya the Great (Rama V, 1868 - 1910) led to increasing use of land transportation as more streets were added to Bangkok (Figure 2.3). Built-up areas started to grow along roads as people changed their mode of transport from waterways to more convenient land routes. By 1900, the urbanised area of Bangkok had expanded to approximately 18 square kilometres with an estimated population of 600,000. Bangkok started to grow outward from the inner city in a jagged, fan-shaped pattern.



Figure 2.2 The location of the Kingdom of Thailand.

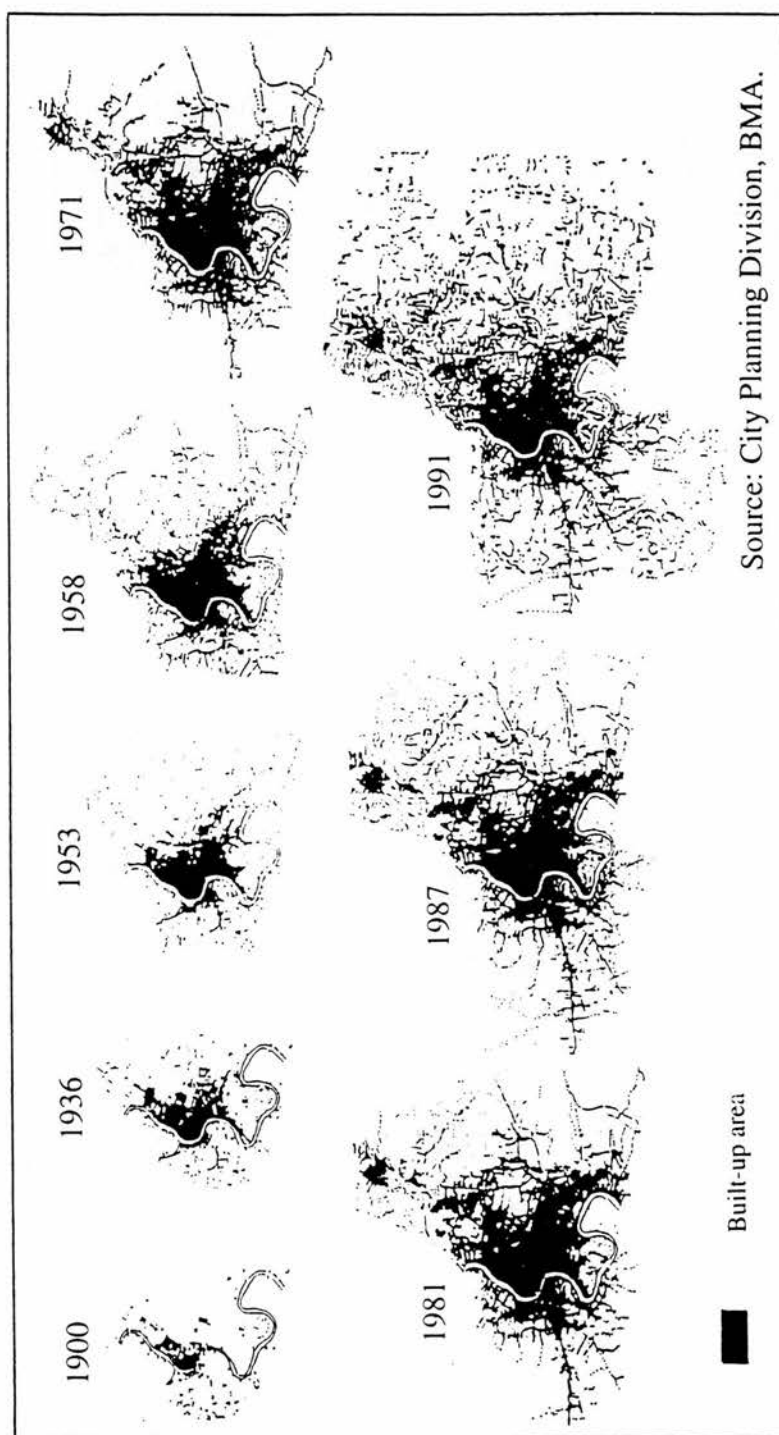


Figure 2.3 Historical development of Bangkok during 1900 - 1991 A.D.

King Rama VI (1910 - 1925) continued the modernisation and more roads were constructed. A planned city designed to symbolise the nation's entry into the modern world was eventually built to the north of the palace. The monarchy also has been a profound influence on the nation since its earliest days. Today, following the bloodless revolution of 1932 in the reign of King Rama VII (1925 - 1932), Thailand is a constitutional monarchy.

World War II had a great impact on the future growth pattern of the city, with many urbanised districts being destroyed in air raids and people moving away from the centre. After the war, Bangkok underwent a decade of construction. In the early 1960s, the growth of Bangkok began to gain momentum due to the large amount of government spending on public utilities. Bangkok virtually exploded and spread out with major thrusts, and many canals were filled. With increasing demand for housing, during the late 1960s and 1970s, land subdivisions and housing estates were developed out into the paddy fields in the east and south. The American involvement in the Indochina war and Thailand's promotion of tourism during 1970s - 1980s have also promoted the growth of Bangkok. By the late 1970s, the western side of Bangkok was experiencing rapid growth as more roads and bridges were built. It is evident that during the five decades since the end of World War II, Bangkok has grown six times in population and four times in urbanised area, and is now one of the largest metropolises in Southeast Asia. The present monarch, King Bhumibol Adulyadej (Rama IX) who ascended the throne in 1946, become the longest reigning monarch in Thai history. Aside from the inevitable vagaries of historical fortune, the development of Thailand shows great continuity. The Thai way has evolved through centuries of steadfastness and independence in body and spirit.

2.3.2 Urban development in Bangkok Metropolis

The Bangkok Metropolis consists of the two former provinces: Phra Nakhon and Thonburi. The two provinces were amalgamated in 1971 (BMA, 1991) to form the Bangkok Metropolis which was later divided into 36 districts (Figure 2.4). As the Chao Phraya River divides the Bangkok Metropolis into two parts, then 25 districts are located on the eastern and the remaining situated on the western bank of the river.

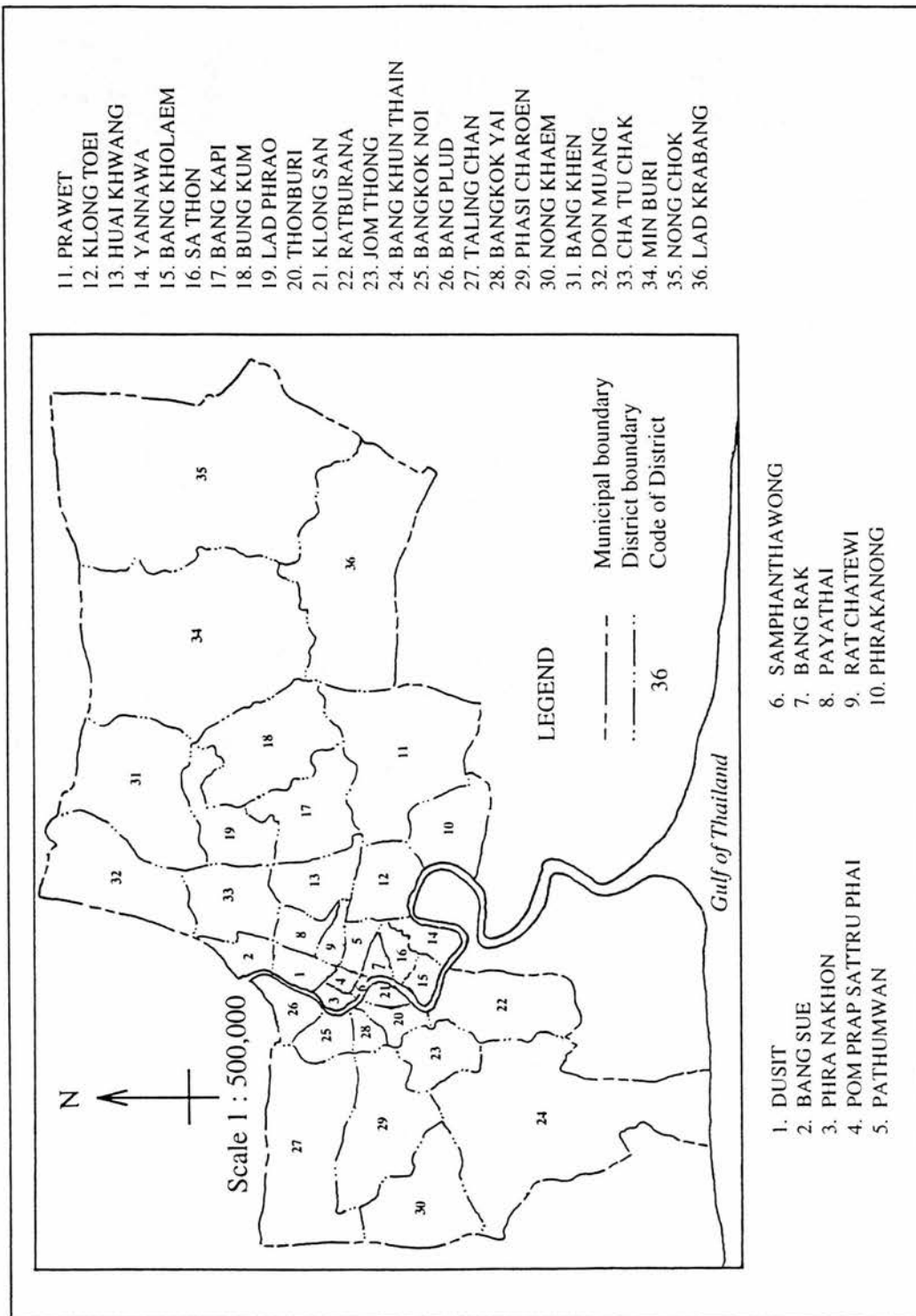


Figure 2.4 The administration boundary of the Bangkok Metropolis.

Generally speaking, the urbanised areas of Thailand are legally designated as a sanitary area and municipality. Both attain their status on the size of the population and the population density living within a boundary. A considerable difference in city sizes and annual growth rates exists among Thailand’s urban areas. Citing statistics on population census, there are approximately 18.7% of the total population or 10.2 million people living in the municipal areas, the remainder (81.3% or 44.3 million) living in the non-municipal areas (Table 2.1). This trend has indicated an unbalanced growth which needed to be adjusted. Bangkok Metropolis had a population of approximately 5.9 million in 1990, and its growth rate is about 3.73% a year, which is more than 32 times larger than Chiang Mai, the largest province in the northern part of Thailand.

Table 2.1 The number and percentage of population in Thailand.

Whole Kingdom	Population (in million)	Percentage
Municipal area	10.2	18.7
Non-municipal area	44.3	81.3

In considering the density by province, it was found that the most densely populated province was still the Bangkok Metropolis with 3754 persons per square kilometre, followed by Nonthaburi, Samut Prakan and Samut Songkhram with a density of 924, 767 and 461 persons per square kilometre respectively. NSO (1990) showed the Bangkok Metropolis, as compared to other provinces, was not only the largest province in term of population but also in term of the number of households, at 1,319,000. The average size of household for the Bangkok Metropolis was about 4.5 persons. As Bangkok is a metropolis of approximately 6 million and the annual growth rate of population is about 4 per cent a year, therefore the related formation of new families creates a need for about 50,000 new dwellings a year.

The Bangkok Metropolis is situated on an alluvial deposit of the Chao Phraya River. The flood plain is suitable for rice plantation and it is covered by some natural and a large number of man-made canals for water distribution, for irrigated farming, as a drainage system, and for transportation. When Bangkok was selected as the new capital 200 years ago there were no roads; transportation was possible only by means of canals. The new capital was later developed as a centre of government, defence, commerce, agriculture and residence during its first century. But during its second century the new technology of urban infrastructure (eg roads, railways, public utility

networks) increasingly required the transformation of the agricultural land for urban development.

As Bangkok Metropolis is situated on the low-lying flood plain, the construction of man-made canals for transportation, irrigation of farm land, and the large number of owner-farmers meant that much of the land was divided into long and narrow irrigated farms, each with a narrow frontage to the canal so as to provide access to the canal's water supply for the greatest number of farms. Consequently, the city has been developed in strips (or so called 'ribbon development') along the canals, leaving large land gaps still under agricultural utilisation (Figure 2.5).

On the basis of aerial photographic interpretation, Thakoerdin (1992) described three dominant land use developments in Bangkok Metropolis, between the current and the previous land use. These can be summarised as follows:

- In the rural areas: paddy fields and orchards were transformed to mixed orchards/vegetables and flowers with low density residential and commercial activities, for example, in the western side of the city.
- In the suburban areas: paddy fields and orchards were transformed to waste or abandoned land or directly to urban development. This development could be clearly seen in the Bangkok urban-fringe area where it appears that a substantial part of the land is owned by wealthy Bangkokian families that prefer to hold the land as a long term investment rather than sell it for subdivision or subdivide it themselves and sell the building sites (Archer, 1983). Moreover, the suburban areas were likely to be developed predominantly for commercial and residential activities.
- In the urban areas: low and medium density residential areas were transformed to high density urban development, with the process of further densification along and extending from major roads. As land values in the built-up areas have risen, development of high-rise buildings is becoming a more dominant characteristic of the areas.

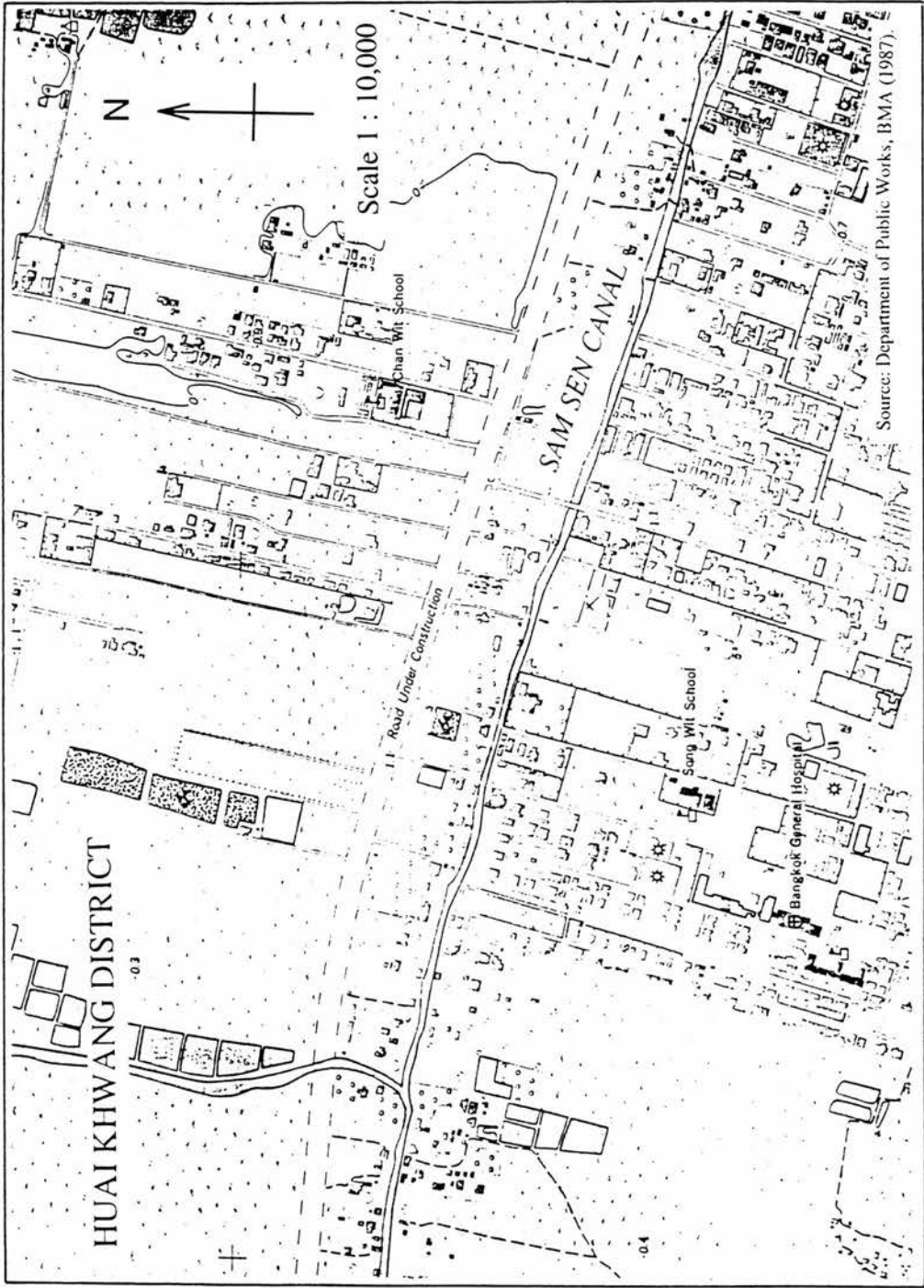


Figure 2.5 The 'strip or ribbon development' in Huai Khwang district, Bangkok in 1988.

2.4 PROBLEMS OF URBAN LAND DEVELOPMENT IN BANGKOK

Bangkok Metropolis is located in the Chao Phraya Basin. The surface of the land within the basin is relatively flat and it is approximately only 0.7 metres above the mean sea level. Therefore the land has a poor drainage rate so that the runoff water from the heavy tropical rains drains away slowly. This means that the existing canals and ponds have to be retained for drainage purposes, even though the existing canals, swamps and ponds become obstacles to the construction of through roads and the development of road networks.

In mixed-economy countries like Thailand, where most land is privately owned, the process of urban development is usually subject to a range of problems. These problems involve the inadequate and delayed provision of network infrastructure, the withholding of land from development, land shortages, scattered and remote land subdivision projects, high land prices and periods of excessive land speculation.

Beyond the pitfalls from the natural phenomena, the transformation of urban-fringe lands by the private sector in the Bangkok Metropolis yields a series of significant consequences for urban land development. Firstly, the land has to be filled with one metre or more of soil to raise it above the level of the annual river flooding, for the construction of roads and buildings. Secondly, most of the land has been divided into many small agricultural farms, often with irregular shapes; when further subdivided, these farms frequently result in unsatisfactory layouts and street patterns. Thirdly, the subdivision and building development of private land has to wait for the construction of public roads in order to gain road access. This means that land with road frontage will gain more development potential and value than land away from the road network. It also means that it is the government road construction program that determines the shape of the metropolis by 'opening up' private land (or so called 'pocket land') for possible subdivision for urban land development.

Fourthly, when the public roads were constructed cutting through these narrow irrigated farms and allowing their subdivision, they could only be subdivided in one way: by placing a long narrow street or lane down the centre with the building site on both sides and with the street or lane often being terminated by a canal. This is the explanation for the 'fishbone pattern' of some of Bangkok's major roads and branching streets, as depicted in Figure 2.6, with inadequate provision of road space

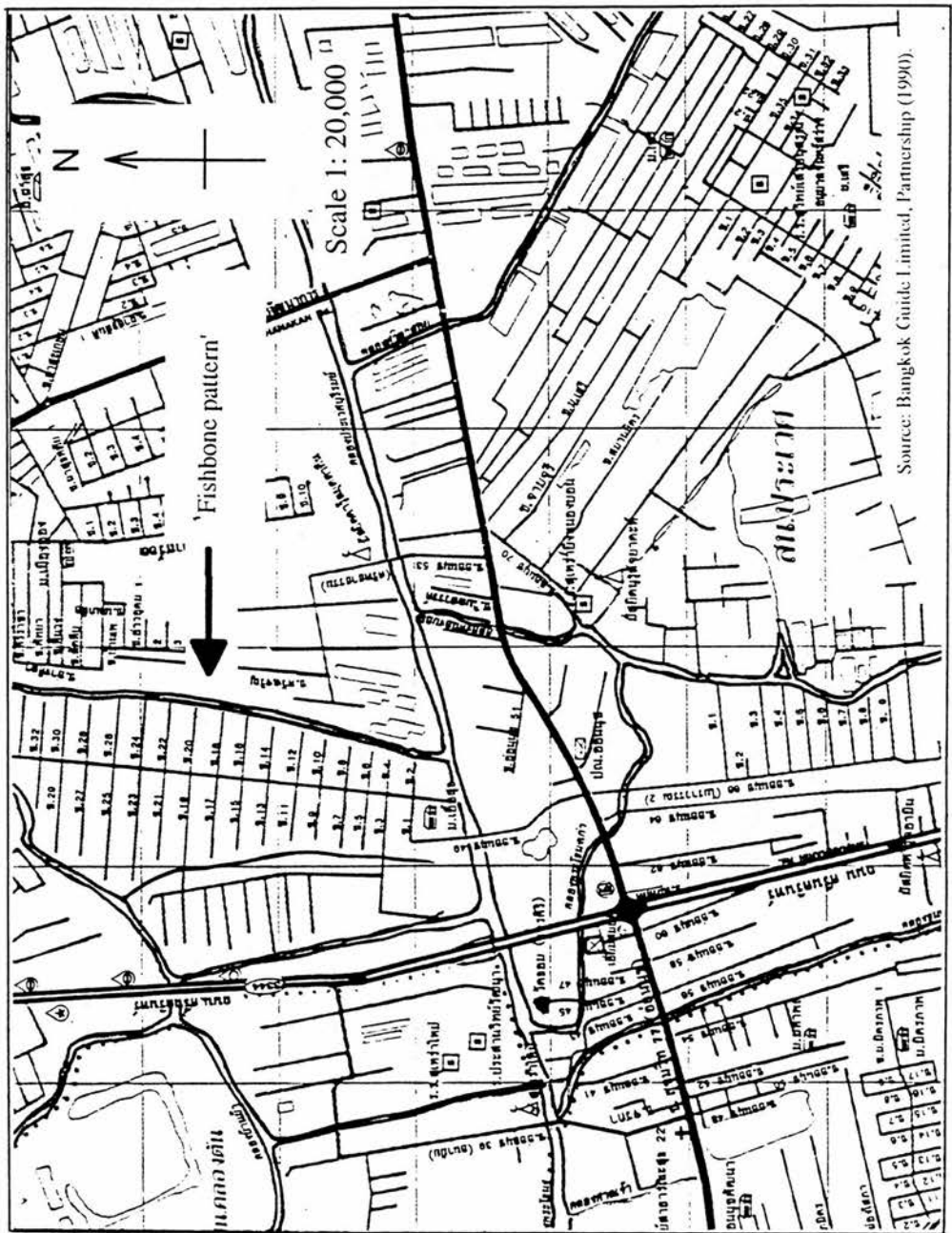


Figure 2.6 A 'fishbone pattern' in the Prawet district, Bangkok.

and the lack of networks of interconnecting streets. This pattern is now also seen as one of the major causes of Bangkok's traffic congestion. The last consequence is that there is a land assembly problem because many landowners do not wish to sell their land. The private land developers find land assembly is a slow and costly process. They have to assemble their land where it is available for sale, which is usually at locations distant from the main public roads. As the developers are able to obtain and provide utility services at any location, the result is that most land subdivision and housing estate projects are at scattered locations with access by narrow and winding streets through earlier subdivision projects.

There is also an urban land development problem in the government sector. The government agencies, such as the Department of Highways and the NHA, require a Royal Decree to be issued to acquire specific lands for expropriation for roads and construction purposes. They are also required to follow cumbersome and time consuming procedures in order to acquire land by negotiated purchase. Furthermore, along with this burdensome administrative procedure, there are the additional barriers of landowner opposition and limited financial resources.

The Bangkok Metropolitan Administration (BMA) is the only agency in charge of constructing the public road system in the Bangkok Metropolis area. The BMA focusses its acquisition and construction program on developing the major arterial roads which are designed to carry through traffic and divide the urban-fringe area into large blocks. It has still no further route plan for constructing and joining systems of distributor/collector roads within each block that would provide a network that the various land subdivision and housing estate projects could connect to. The limited road networks within each block are a series of ad hoc projects in the Bangkok Metropolis, especially road extensions on lands donated by private landowners or upgrading roads transferred from the private subdivision projects. Archer (1985) indicates that the resultant pattern of urban land use is a patchwork of scattered subdivision and housing projects connected by a maze of narrow local roads, mainly from earlier subdivision projects.

2.5 LAND READJUSTMENT IN GENERAL

Land is a term of various meanings. To the physical geographer it is a landscape, the product of geological and geomorphological processes. To the economist it is a resource which, along with capital and labour, is to be exploited or conserved in order to achieve economic production and development. To many it is simply the space for human activity as reflected in the many different forms of land use. The land is man's most valuable resource (Dale and McLaughlin, 1990). In the present context, the land forms a base for most human activity. Obviously, therefore, systematic records of land and rights in land have great importance for public administration, land planning and land development, and for private transactions in land. This situation is particularly true in those developing countries where the rapid growth of population has caused increasing pressure on rural land, while simultaneously a massive migration of people to cities and towns led to the uncontrolled growth of urban centres.

Modern urban areas are burdened with many problems such as: population concentration, deterioration of living environments, traffic congestion, insufficient housing, urban sprawl phenomena and other disasters. Land readjustment is one of the major keys to the solution of these problems.

2.5.1 The definition of land readjustment

There have been many attempts to define land readjustment. Most definitions can be overturned or superseded by later definitions because land readjustment is an ongoing process still widely applied in many countries the world over. Land readjustment tends to be thought of as a technique for the financing and management of the subdivision of privately owned land into well-planned serviced building sites.

Archer (1992) offered the following definition:

'Land readjustment is a technique for managing the planned development of urban fringe lands, whereby a government agency consolidates a selected group of land parcels and then designs, services and subdivides them into a layout of streets, open spaces and serviced building plots, with the sale of some of the plots for cost recovery and the distribution of the remaining plots back to landowners to develop or to sell for development'.

Masuchika *et al.* (1982) simply refer to a land readjustment as a method of rearranging land uses in order to facilitate a greater utilisation of the land through the provision of basic public facilities and infrastructure and the alignment of the new building sites in relation to these facilities and infrastructure. The cost of these public improvements is derived from the sale of land proportionately offered by each affected landowner or through an impartially levied assessment on all lots within the project limits. CPB (1982), the city of Nagoya (Japan), defines land readjustment as 'a technique by which public facilities in a certain area, such as roads, parks and sewerage that are necessary for life, are created and/or improved, and individual sites are made easier to use and their site utility is increased by dividing them into more regular shapes'. Yomralioglu and Parker (1993a) have suggested that land readjustment is a 'planning tool to assist in systematic urbanisation. Its main objective is to transform undeveloped land parcels into appropriate forms according to land-use planning needs'. NESDB (1994) point out that land readjustment is a 'land management technique by which a selected group of adjoining land parcels in an urban-fringe area are consolidated for their unified design, servicing and subdivision into a layout of roads, open spaces and land parcels and building plots, with the sale of some of the new parcels/plots for project cost recovery and the distribution of the other parcels/plots to the landowners'; while Buranasiri (1992) describes land readjustment as 'a technique to enable an increase in land supply by rationalising all land holdings in a designated area and providing the areas with the necessary infrastructure. After readjustment, a portion of the newly serviced lots is transferred to the public developer as a cost of planning and infrastructure installation. The landowners get a small amount of fully serviced land, giving him or her the value assets'.

Seele (1982) defines land readjustment as an 'instrument for land organisation, which means both the provision of land needed for public purposes (especially transport and green areas and ground for public use) and the suitable formation (location, shape, size) of private land according to the rules of town planning. Land organisation can come about by voluntary arrangements (private land organisation) or by compulsory measures (sovereign land organisation). Sovereign land organisation is only utilised when the desired purpose cannot be attained by private land organisation'. Moreover, Lee (1982) refers to land readjustment as a 'valuable innovation for land reform and urban reconstruction. It consolidates small parcels of land, irregular plots, and lands unsuitable for economic use into usable parcels by exchanging, dividing, and

distributing them’ and goes on to point out that land readjustment redemarcates the land boundaries and constructs public utilities according to the detailed urban-planning programme and related laws while maintaining the participants’ land ownership. It can also increase land utilisation to meet the ideal of ‘maximum use of the land’ and also save the government a great deal of money.

For the purposes of this thesis, a land readjustment can be considered on several levels. At the most basic level, it can be considered as a technique for land reform and urban reconstruction. At a low level, it can be considered as a method of rearranging land use so as to facilitate a considerable utilisation of the land through the provision of basic public facilities and infrastructure. At a medium level, it can be deemed as a planning tool to help meet the requirement of urbanisation. At a high level it can be regarded as a land management technique involved with city planning, financing, spatial and aspatial data handling.

With common principles and procedures, land readjustment has been adopted in many countries under different terminologies (Table 2.2).

Table 2.2 Land readjustment under different terminologies.

COUNTRY	TERMINOLOGY
Australia	Land pooling
Canada	Land replotting
France	Land reconstruction
Germany	Land regroupment
Italy	Land realloiment
Israel	Land reparcellisation
Norway	Land consolidation
Spain	Land realloiment
Taiwan	Land consolidation
United States	Land reassembly

It can be seen from Table 2.2 that the terminology in Germany for example, is ‘land regroupment’. The technique is mostly carried out in peripheral areas for urban expansion and in urban areas for renewal. Other terminologies which refer to the principles and management concepts of the land readjustment include ‘land consolidation’ in Norway and Taiwan, ‘land pooling’ in Australia, ‘land replotting’ in Canada, ‘land reconstruction’ in France, ‘land reparcellisation’ in Israel, ‘land realloiment’ in Spain and Italy and ‘land reassembly’ in the United States.

2.5.2 The difference between land pooling and land readjustment

There is an important legal difference between the land pooling practised in Australia, and the land readjustment practised in Japan, Korea and Taiwan. In the former, the ownership of the land is actually transferred from the landowners to the pooling agency and then back to the landowners, whereas in the case of land readjustment the ownership remains with each landowner, but with restricted ownership rights, and the readjustment agency is permitted to enter and undertake construction activities on the land. When the land servicing and subdivision works are completed, there is an instantaneous transfer of ownership by the exchange of old parcels for new plots. Under land pooling, the original land parcels are actually consolidated into one parcel whereas under land readjustment they are only notionally consolidated for design and construction purpose.

2.6 THE CHARACTERISTICS OF LAND READJUSTMENT

Land readjustment is a technique for the financing and management of the subdivision of privately owned land into well-planned serviced building sites. It is based on a scheme, or plan, prepared by a local municipal council, after consultation with the landowners involved, but after proper adoption it constitutes a binding and compulsory partnership among the owners for the design, servicing, and subdivision of their lands as a single estate, with both costs and returns being shared among them. It improves land development by avoiding the problems associated with piecemeal activities and increases the efficiency of financing and construction (Doebela, 1982). Although land readjustment has been introduced and has succeeded in many parts of the world such as Germany, Japan, Taiwan and South Korea, it is a relatively new concept in Thailand. Consequently, the institutional structures have only recently been set up; and co-operation between various concerned agencies needs to be fostered and approaches need to be established. The main characteristics of land readjustment can be summarised as follows:

(1) The main objective of land readjustment is to convert developed land parcels of irregular shape into suitable forms according to town planning requirements. Moreover, land readjustment is carried out for the areal development of urban areas, and its goals are developing and improving public facilities, achieving greater

utilisation of land, creating a well-organised urban area and contributing to the welfare of society.

(2) Owners of land in the project area are asked to contribute an equitable portion of their lands which are pooled and replotted into three portions:

- (i) the first and largest portion is allocated to the 'new private plots',
- (ii) the second is the 'contribution' for local private roads, infrastructures and facilities,
- (iii) the third is the 'reserved' portion which is sold to generate income to finance a part of the project expenses.

(3) Owners of land, leaseholders and other persons who have some right within the project area can maintain their everyday life and business activities with minimum interruption during the project period.

(4) There is no waste in land use since land conditions are altered over the whole land readjustment area.

(5) The land registration books, cadastral maps, street names and numbers can be arranged in an orderly manner, demarcating the new parcel boundaries of ownership. Therefore, the practice of land readjustment can be considered as a way of strengthening the reorganisation of the cadastre (Chou and Shen, 1982).

(6) From the legal point of view, where land readjustment projects are implemented, there is normally legislation which binds the landowners to participate. In some countries, legal support for land readjustment is stipulated by related legislation such as the Fundamental Land Law in the case of Indonesia. In Germany, Japan, South Korea, and Taiwan, there are specific legal systems for land readjustments. In Japan, the legislative framework for land readjustment dates back to the City Planning Act of 1919. The current land readjustment law in Japan is an amalgamation, amendment and modification of the laws and regulations of the past 75 years from the 1919 Act.

(7) Most land readjustment projects are carried out by local government authorities but they are sometimes undertaken by central government bodies such as public housing authorities or highway authorities. They can also be carried out by a group of

neighbouring landowners by forming a co-operative company or association to manage the pooling servicing, subdivision and redistribution of their lands.

(8) A majority of the landowners in a proposed pooling area understand and support the use of land readjustment.

(9) Land readjustment is confined only to re-parcelling of land, and construction of basic infrastructures. It does not normally involve alterations to most of the existing building structures, but if demolition is necessary, compensation is paid.

2.7 THE POTENTIAL BENEFITS OF LAND READJUSTMENT

The conversion of urban-fringe lands from rural to urban uses usually takes place by the subdivision of the separate land holdings and is subject to the problems of scattered land and building development, poor subdivision design, land shortages, excessive land speculation and high land prices. It is evident that land readjustment can reduce these problems; it can provide many of the benefits of large-scale land development projects.

In this thesis, some of the expected benefits from the point of view of the private sector, namely the landowners, and then the public sector are discussed in the following sub-section.

2.7.1 Land readjustment benefits for landowners

Apparent benefits from the perspective of the landowners occur in the following areas:

- Land readjustment can create access to public roads.
- Land readjustment can ensure a fair sharing of the costs and benefits of land development.
- Land readjustment can improve the urban living environment, because part of the contribution ratio is set aside for public areas which can be used as children's playgrounds, parks, etc..
- Land readjustment can ensure a wider distribution of benefit from the land price increase generated by subdivision, for example, because increase in land prices

will not be concentrated along the main road frontages as occurs with ribbon development.

- Land readjustment can counter the problem of excessive land speculation and ensure an adequate supply of land for new housing development.
- Land readjustment can create new sites with clear land titles when the ownership of land holdings is disputed.
- Fragmented small parcels are consolidated into a single new building parcel so that land use is maximised.
- Land readjustment can ensure a higher level of efficiency in land use.
- The concept of land readjustment, however, is not an original approach found only in the capitalist-style reconstruction of urban centres in Japan. It is of benefit as a method to increase agricultural productivity and to improve arable lands from a landowners' perspective (Satoh, 1986).

2.7.2 Land readjustment benefits for the government

The most apparent benefits from the perspective of government are as follows:

- Land readjustment can provide the land for open space and public streets at no cost to government. For example, in the context of Thailand, land readjustment can be adopted to acquire land for the construction of secondary road networks, thus partly reducing the ever increasing traffic problems especially in Bangkok.
- Land readjustment can be adopted to reduce public spending. With contributions from the private landowners, the bottlenecks in the public spending can be greatly reduced and with it, there are increasing prospects of better and adequate service coverages.
- Land readjustment can be adopted as an instrument in avoiding the problems of 'ribbon development' common to almost all road construction projects: and at the same time, opens up 'blind land'. It is evident that land readjustment provides a wider and more equitable distribution of benefits from the infrastructure development.
- Land readjustment can be used as a tool, as in the case of South Korea, to generate land for low-income housing.
- A zoning plan is realised in a short time, and urban land development projects are achieved rapidly.
- Tax revenue increases within the project area. This provides an extra source of income to government.

- The land development programmes in urban-fringe areas are carried out systematically.
- The existing cadastral records are updated, reorganised and cadastral administration is improved (Yomralioglu and Parker, 1993b).

2.8 LAND READJUSTMENT IN OTHER COUNTRIES

Many cities in both developed and developing countries are facing an increasing rate of urban sprawl. After World War II, urbanisation progressed rapidly while governments did not have sufficient measures to implement effective programs to cope with problems in advance because they had to carry out national development in chaotic situations generated by war damage, national independence, and other natural disasters. Partly because of lack of serious efforts to cope with urban development and partly because of rapid urban growth and financial difficulties, urban problems such as traffic congestion, uncontrolled expansion of urban areas and growth of slum areas were aggravated year after year. At the same time, large cities began to play major roles in national production and economic activities; as a result, a need for urban development has been set as a top priority development programme by several governments and international organisations.

Furthermore Doebele (1982) recorded that many methods, such as nationalisation of land, government ownership of peripheral areas (land banking), have been proposed to resolve these problems. Among the most interesting, least known devices in this field is 'urban land readjustment' which, as already described, is also known as 'urban land consolidation' or 'urban land pooling'. This method has become an important tool for urban development in Germany, Japan, South Korea, Australia, Taiwan, and Indonesia.

2.8.1 Land readjustment in the Federal Republic of Germany

In the Federal Republic of Germany land readjustment for urbanisation was adopted by Frankfurt-am-Main in 1902 and has continued in Germany ever since. Its origins were land consolidation for farmland and woodland. In Germany, land readjustment is an instrument for land organisation, which means both the provision of land needed for public purposes and the suitable formation of private land according to the

rules of town planning. Land organisation can come about by voluntary arrangements (private land organisation) or by compulsory measures (sovereign land organisation). Sovereign land organisation can either be carried out by compulsory purchase, by compulsory readjustment, or by boundary regulation. In most cases, the legal and actual circumstances require land organisation by compulsory readjustment.

Compulsory readjustment is a procedure to subdivide real estates (plots) in a suitable way with respect to location, shape, and size by: adjusting to the binding development, and micro zoning plan, and to other building laws; providing land for development facilities (transport, parks, and green areas) from all landowners equally; and not reducing the basic substance of land ownership. Compulsory readjustment is carried out by local authorities on their own responsibility if necessary for the realisation of the development and micro zoning plan. In all cases, compulsory readjustment must keep to the development and micro zoning plan, including: kind and extent of building use: pattern of site layout, building line, and position of buildings; minimum size, width, and depth of building plot; land for community or social purposes (schools, hospitals); land for traffic, pedestrians, and parking; land for electricity, gas, and other utilities; and public and private green areas.

However, compulsory readjustment does not always satisfy the interests of land ownership (willingness to sell, economic and political status of landowners, size and shape of lots). On the other hand, compulsory readjustment forces a critical discussion of the landowner's interests and does bring about balanced and realisable planning. To sum up, land readjustment projects in Germany are carried out by local government, they are compulsory and they do not require the landowners' consent.

2.8.2 Land readjustment in Japan

Japan adopted the German model of rural land pooling to the period after the Meiji Restoration (1868). The government, by enacting the Agriculture Land Consolidation Law (ALCL) in 1899, promoted the land readjustment of farmland boundaries to improve agricultural production.

'Tochi Kukakuseiri' or land readjustment was again introduced in Japan during the 1920s. Enacted as part of the City Planning Law of 1919, the early structure of the

land readjustment system was deemed as a method of alleviating the negative impacts of industrialisation within the population centres of Japanese cities. Through this early version of land readjustment, land uses were rearranged to promote a greater utilisation of land and to provide public facilities (eg roads, parks, utilities). Since the beginning of the Showa Era, extensive projects have been carried out in Tokyo, Nagoya, Kyoto, and other localities. Then, on the basis of subsequent land readjustment experiences covering more than 35 years and particularly the redevelopment projects following the Great Earthquake in 1923 and the war-damage of World War II, an independent law known as the current land readjustment law was enacted in 1954 (Miyazawa, 1982).

In other words, the current land readjustment law is an amalgamation, amendment and modification of laws and regulations of the past 75 years from the City Planning Law launched in 1919. This national law provided guidelines for the urban renewal of blighted areas in order to upgrade public facilities and to effect the reallocation of the residential and other building sites simultaneously by boundary changes creating better shaped lots in relation to these new facilities.

Land readjustment in the Japanese system has depended much more heavily on private landowners voluntarily organising themselves in the full sequence of operations, including making their own site plan for their collective holdings, determining the cost of infrastructure installation, establishing the amount of cost-equivalent area, executing public works, and making the final sales of the cost-equivalent lots to defray the costs.

2.8.3 Land readjustment in South Korea

The introduction of land readjustment in South Korea occurred during the Japanese occupation of 1910-1945. The first land readjustment projects were government initiated in rural areas. The costs of purchasing land for arterial roads, school buildings, parks, and conduits, as well as the costs for engineering work, were imposed upon the landowners within the area, who bore the financial burden because the implementing agency lacked the financial resources to cover such costs. Land readjustment was used on a wide scale during the 1930s to consolidate and regularise rural land holdings, widen rural roads and provide sites for public facilities in villages.

Many successful projects in South Korea have been carried out since World War II in the suburbs of Seoul, where the shortage of houses has been heavily exacerbated by the ever-growing inflow of population. Conversely, in small towns in the country, projects have often encountered strong resistance and complaints from landowners because land prices did not increase to the anticipated level. Although development-related construction work was deferred for several years in small towns, the residents of such areas now generally agree that projects are worthwhile undertakings, both benefiting landowners who want their land developed and furthering national interests by promoting the diversification and improved utilisation of private land (Kim *et al.*, 1982).

Urban land readjustment began in 1936 under the Urban Land Planning Ordinance based on the Japanese planning law of 1923. This ordinance was replaced by the City Planning Law of 1962 and then by the Land Readjustment Project Law of 1966 which is administered by the Ministry of Construction (Archer, 1984). Land readjustment in South Korea is carried out by local governments, landowner associations, the Ministry of Construction and the other national government development corporations engaged in land, housing and industrial estate development. Most urban development in South Korea is carried out through pooling projects, but some local governments and the other development corporations also undertake a considerable amount of land development on land that they have purchased, by both negotiated and compulsory purchase.

2.8.4 Land readjustment in Australia

Perth, the capital of Western Australia, has developed over the last 160 years as a low-density metropolis. Although the First Schedule of the original Town Planning and Development Act of 1928 contained a provision for land pooling, no local council in Perth used this power until 1951. This delay was largely because of the economic depression of the 1930s and World War II, when there were little urban growth and development. Since the first pooling project, in which local government councils act as the pooling agencies, was begun in Perth in 1951, over forty projects have been undertaken, with a continuous increase in size and general acceptance of the technique. By 1982, some 54 pooling projects had been commenced by ten local governments in Perth.

Most of the Perth pooling projects have been implemented successfully, giving the landowners attractive land value gains, saving the local governments the cost of the infrastructure works and public facilities, and providing the residents with pleasant and well-equipped residential suburbs. This has been done within a reasonable time period. However, some projects have been unsuccessful in that the landowners have experienced little gain in land value and/or have been locked into projects delayed for years due to poor project formulation and management. These projects demonstrate that the benefits of land pooling are not automatic but have to be achieved by good management, that is, by the formulation of sound projects with the efficient implementation of the project. This requires skilled and efficient project managers.

The Perth experience has shown that pooling is a land-development technique that can be used to improve the standard, efficiency, and financing of urban land development. This experience has also shown that it could be widely adopted for achieving the planned development of privately owned lands, because it is politically, and administratively feasible. However, the Perth experience does not appear to have been repeated elsewhere in Australia.

2.8.5 Land readjustment in the Republic of China (Taiwan)

Urban land readjustment is usually referred to as urban land consolidation in Taiwan, reflecting its links with the programme for rural land consolidation. Virtually all the land readjustment undertaken in Taiwan has been carried out since 1958, first in rural and then in urban land.

After moving its seat to Taiwan, the Chinese government was determined to launch a series of progressive measures to achieve land reform which commenced in 1949. Rural land readjustment began after the completion of the land reform. Many projects were undertaken on a trial and demonstration basis during 1958-1961 and then under the first rural land readjustment programme of 1962-1971 followed by the second programme of 1977-1982. The first urban land readjustment was begun in 1958 in Kaohsiung, one of the densest areas of Taiwan. The Kaohsiung City Government has been the leading local government in the use of land readjustment, undertaking the first urban project in 1958, launching a programme of projects in 1971, completing 21 projects by 1982, and formulating a set of project regulations that were adopted for general use by local government by their inclusion in the Bylaw of the Statute in

1964. To carry out its land policy, the government of the Republic of China has enacted the Land Law, the Land to the Tiller Act, the Regional Planning Law, the Urban Planning Law, the Equalisation of Land Rights Law, Measures for Land Consolidation, and several other laws and regulations designated to promote land use. Many laws are administrated by the Department of Land Administration in the central government and by the Provincial Land Bureau at the provincial government level.

2.8.6 Land readjustment in Indonesia

Indonesia is the first Southeast Asian country to adopt a land pooling/readjustment (LP/R) technique. The Directorate-General Agraria (D-G Agraria) has taken the lead in introducing and implementing LP/R in Indonesia. As the national department of lands, it is responsible for administering the law and policy on land ownership and land use, and is organised as four central directorates for land use, land rights, land registration and land reform, and as 27 provincial directorates. Although many officials have visited Taiwan, its LP/R projects are not imitated exactly on the Taiwan LP/R projects. Whereas the Taiwan projects are directed towards both providing the land required for public and community purposes and installing the network infrastructure at no cost to government, the D-G- Agraria projects have been focused on the land components and have not included the construction of network infrastructure.

The main reason that the D-G Agraria projects are focused on these land objectives rather than both land and infrastructure objectives is uncertainty about the maximum percentage land reduction (about 20 per cent of their land area) that all landowners will accept. Above all, many landowners attach more importance to their land area than to its market value, particularly if they intend to continue farming their land rather than sell it immediately for building development. Their reluctance to give up additional land in order to finance the construction of infrastructure works would also be influenced by the fact that these works are usually constructed by the government at no cost to the landowners.

The D-G Agraria proposed the first LP/R project in 1979, commenced it in 1981 and effectively completed it in 1985. By late 1986, D-G Agraria had completed 4 other LP/R projects in Bali and another 8 projects in eight other provinces. With 13

projects completed, D-G- Agraria had another 15 projects in progress; one in Bali and the remaining projects in eleven other provinces. Another 2 LP/R projects are being carried out as pilot projects by two local governments under the guidance of the Centre for Land Research and Development in the Ministry of Home Affairs.

In summary, there is much variety in the different practices adopted by countries involved in land readjustment, and not much common ground. Land readjustment projects in Germany are carried out by local governments, they are compulsory and do not require the landowners' consent. In Japan, land readjustment has heavily depended on private landowners voluntarily organising themselves while in South Korea most land readjustment has been initiated by the government. Local government agencies in Australia have been permitted to undertake land pooling since 1928, but it did not come into active use until 1951. With respect to Taiwan, land readjustment has reckoned on government and has roots that precede the great interest in agricultural land reform in the period after World War II. In Indonesia, although no law has been enacted by the government since 1981, land readjustment projects have been implemented through the negotiated agreement and co-operation of all the landowners.

2.9 THE CURRENT STATE OF LAND READJUSTMENT IN THAILAND

Although land readjustment has been applied and has succeeded in many parts of the world as described above, it is a relatively new concept in Thailand. As a result, the institutional structures have been set up only recently. The Cabinet officially approved the principle of land readjustment on March 6, 1992. By the Ministerial Order of the Ministry of Interior (MOI) No. 305/2535 dated May 1, 1992, the National Urban Land Readjustment Committee (NULRC) was appointed as the highest authority on urban land readjustment at the national level. The NULRC later appointed the Sub-Committee for drafting the Legislation for Urban Land Readjustment. Within this latest version, decision making, setting the policy and supervision of the operations of the Office of Urban Land Readjustment fall within the mandate of three main institutes. These include the NULRC, the Bangkok Metropolitan Urban Land Readjustment Committee (BMULRC), and the Provincial Land Readjustment Committees (PLRC). At the top of the institutional structure is

the Minister of Interior as Chairman and the under-secretary of State for Interior as Vice Chairman (Figure 2.7).

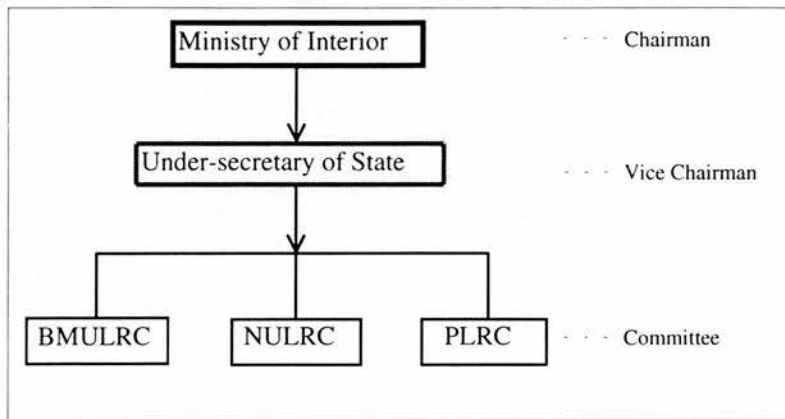


Figure 2.7 The structure of the National Urban Land Readjustment Committee in Thailand.

The membership of the NULRC also includes the heads of 13 other public organisations whose mandates are related to land readjustment and 5 other committee members to be appointed. The Director General of the Department of Town and Country Planning acts as a Committee Member and Secretariat.

2.9.1 The Department of Town and Country Planning

In 1988, the Department of Town and Country Planning (DTCP), with the technical assistance of the Japanese International Cooperation Agency (JICA), undertook a pilot study on the feasibility of land readjustment as a technique for the planned urban development of a new town in Laem Chabang, Chon Buri province, the exercise being a component within the Eastern Seaboard Development Project. The Laem Chabang New Town area, covering an area of 1600 rai or 256 hectares, was selected for the land readjustment study for two reasons. Firstly, it offered the convenience of an already-prepared development plan. Several technical studies (eg 'Technical Study for Preparation of Laem Chabang Coastal Area') had been prepared, and the staff of the DTCP were well acquainted with the study area through the preparation of its specific plan. Secondly, it offered a test case for showing how the specific planning system can be made practical and functional.

At the present time (1994), the DTCP and JICA are also carrying out a pilot land readjustment project in an area near the RAMA 9 Road, Huai Khwang district,

Bangkok. The pilot project covers a total area of 5000 rai or 800 hectares. The purpose of this study is to arrange that urban functions and industries should be redistributed away from the existing Central Business District (CBD).

In addition, the DTCP is also involved in land readjustment in two other areas. The first site is in Koh Kret in the Pak Kret district, Nonthaburi province, where the Nonthaburi municipality is reported to have submitted a request for the DTCP to undertake land readjustment with some 252 registered landowners (with a total land area of 1149 rai or 184 hectares) who have agreed to join in the project. The second site is in the Muang district in Lop Buri province where land readjustment would be used for the procurement of land for road construction in accordance with the provincial town plan.

With regard to the dissemination of ideas concerning land readjustment, the DTCP and JICA experts have held seminars including representatives from various agencies in government and non-government sectors and members of the media. The seminars were focused on generating discussion, exchanging ideas over the legislative aspects, and were also organised for the purpose of providing an understanding of the concepts as well as practical training on land readjustment techniques.

2.9.2 The National Housing Authority

The adoption of land readjustment by the National Housing Authority (NHA) could be considered to have been influenced by South Korea which generated land for the construction of low income housing. The NHA has experimented with a number of options to obtain affordable land, including the construction of flats for rent and hire-purchase, developing housing estates and new towns and upgrading slum communities.

In 1992, the NHA proposed a pre-feasibility study of land readjustment, based on a study area located west of Romklao community in the Lad Krabang district, which is designated as a low density residential zone in the Bangkok Metropolis General Plan. The land readjustment project, covering an area of 688.65 rai or 110 hectares, was proposed with two different development scenarios. The first includes the cost of complete land filling for the whole project area; the project cost estimation is about

514 million Baht. The second involves only partial land filling and the construction cost would be substantially lower at approximately 254 million Baht.

Up to now, there has no progress about the results of the pre-feasibility study been reported by the NHA. It is, however, worth noting that there has been a housing project which is undertaken by a private sector located in this area since the early of 1993.

2.9.3 The Bangkok Metropolitan Administration

Bangkok Metropolis is now struggling from the pressure of urban growth while suffering from shortage of infrastructure and resources to meet current predictions of future demand. Efforts to meet the infrastructure needs have come up with a new urban management policy on the integration of physical planning and infrastructural investments.

SOFIE (Phase I)

The Study of Options for Financing Infrastructure Expansion (SOFIE), which was jointly conducted by the Land Institute Foundation (LIF) and the Planning and Development Collaborative International (PADCO), was commissioned by the Office of National Economic and Social Development Board (NESDB) in order to determine how the national policies relative to private sector participation in the financing of infrastructure could be operated and to develop infrastructure financing and beneficiary payment policy alternatives for the Seventh National Social and Economic Development Plan period (1992-1996).

The study area of the first Phase was located between the Phahon Yothin Road and the Rattanakosin Sompoch Road in Bang Khen district. The area was chosen by the MOI and covered an area of 4830 rai or 773 hectares (Figure 2.8). The area situated along the Phahon Yothin Road has been commercially developed with a large shopping complex. Within the project area, moreover, there are a number of housing projects. It is estimated that around 58 per cent of the area remains undeveloped. However, the choice was mainly influenced by the objective of restructuring the planned B2 Road as shown in the Bangkok Metropolitan General Plan 1992 (Figure 2.9).

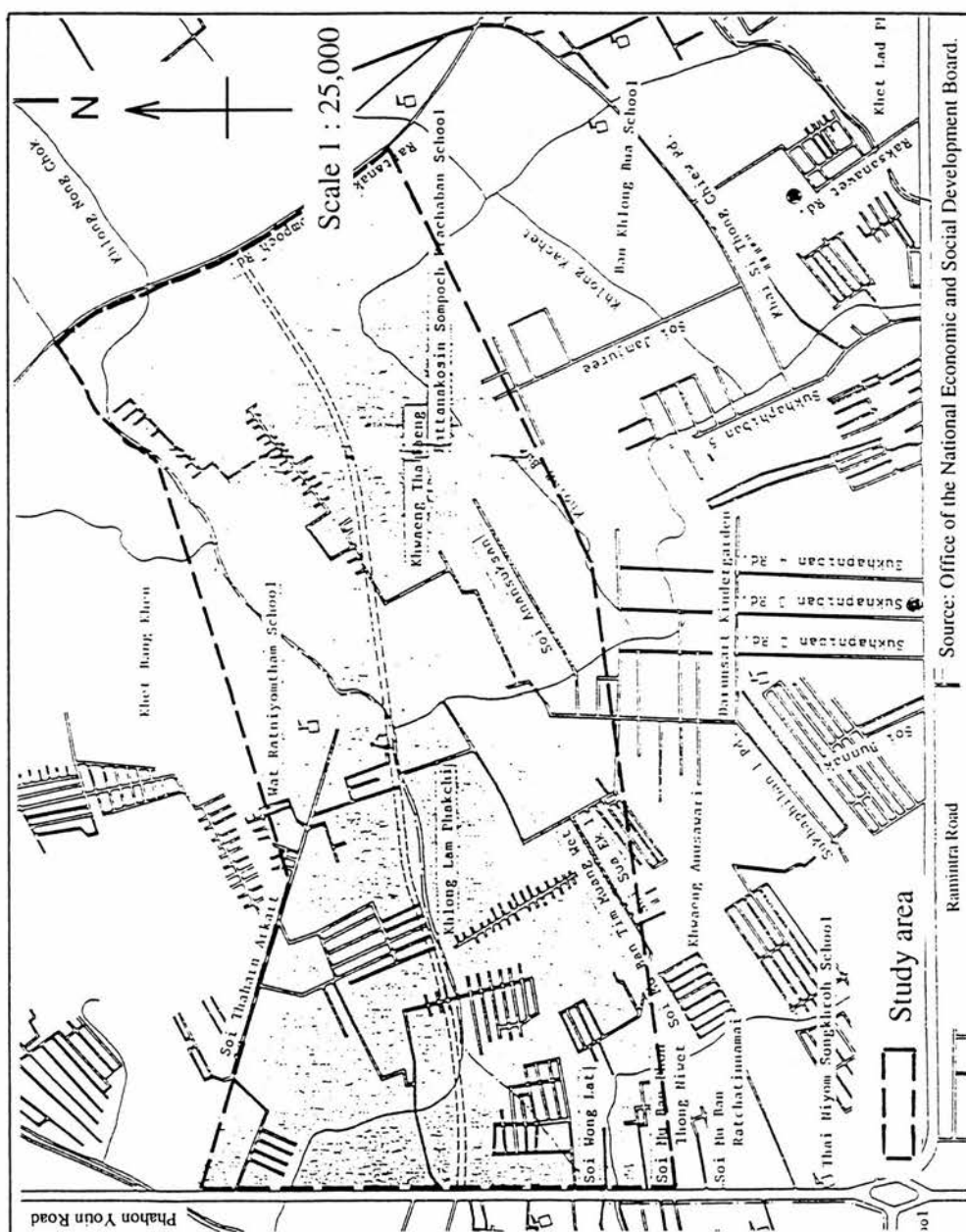


Figure 2.8 Study area of Phase I.

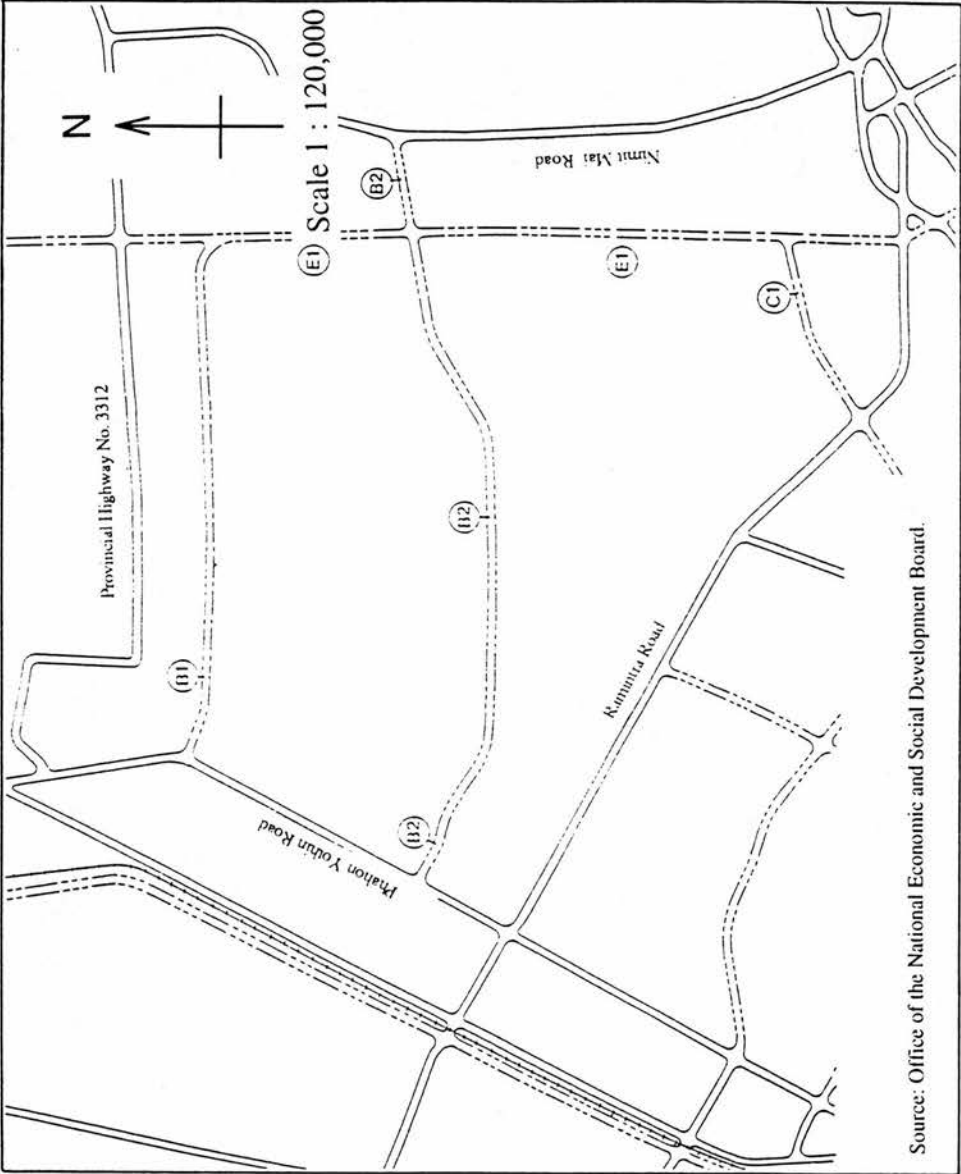


Figure 2.9 Road network plan of the 'super block'.

The first Phase of the SOFIE (SOFIE I) has concluded that national, regional and local government agencies in Thailand could apply a variety of infrastructure financing options as aspects of specific, formally-endorsed, spatial planning and land development strategies. The five broad development strategies are as follows:

- growth management;
- development co-ordination;
- strategic sites;
- development opportunities;
- criteria-based allocation.

Since the total infrastructure requirements of Thailand probably cannot be satisfied by the Government, which heavily depends on public funds for its operations, private sector capital resources must be a significant component of future infrastructure financing schemes. The study then went on to identify seven beneficiary payment mechanisms which could be adopted. These techniques which were later endorsed and incorporated into the Seventh Plan were:

- property taxes;
- user charges;
- subdivision regulations;
- special assessment;
- land readjustment;
- development fees;
- excess expropriation.

In SOFIE I, land readjustment was finally recommended to be an indispensable tool for supporting the Seventh Plan implementation. The potential of land readjustment is so promising that further in-depth assessment of the legal, institutional and operational requirements should be a high priority.

SOFIE (Phase II)

It is in this connection that the SOFIE Phase II (SOFIE II) project is conceptualised. The objectives of the pilot study under SOFIE II are as follows:

- to demonstrate the technique of urban land readjustment;
- to convert rural land into urban land with a well planned layout of streets, open spaces and serviced building plots with full project cost-recovery;

- to ensure that landowners would benefit from increase in land value after land readjustment.

At the time of writing (1994), SOFIE II is still in progress, and two sites are under investigation.

Site 1

The NULRC authorised the BMA to use the land readjustment technique to implement the first section of the B2 Road and the NULRC also set the preliminary boundaries of the possible land readjustment project area. The BMA team from the City Planning Division studied this area by field survey and using aerial photographs and existing cadastral maps. Site 1, as shown on Figure 2.10, was chosen as a promising area for an investigation for the preparation of a land readjustment project. The location of Site 1 is about 2 km east of Phahon Yothin Road and 1 km north of Ramintra Road. The pilot study area covers an area of 1035 rai or 166 hectares in Bang Khen district. The BMA team also divided the Site 1 area into five blocks so that the landowners in each block could be surveyed to ascertain their interest in accepting and joining a land readjustment project. In addition, the concept of breaking the area into five blocks was mainly influenced by the constraints of the BMA in terms of budget, manpower and resources which will necessitate the phasing of land readjustment activities since the number of the blocks do not reflect the stages of implementation. It was generally agreed that land readjustment would start in the blocks where the landowners were more ready to endorse land readjustment measures.

The BMA team has also designed a road layout plan for the whole of the Site 1 area. The replanning and reconstruction proposed for the Site 1 area will be for low density residential land use in order to follow the land use zoning shown in the Bangkok Metropolis General Plan. However, if part of the Site 1 area is replanned and divided into suburban shopping, business, and civic centre, then the land readjustment project will generate a bigger increase in land values which make the project financially viable.

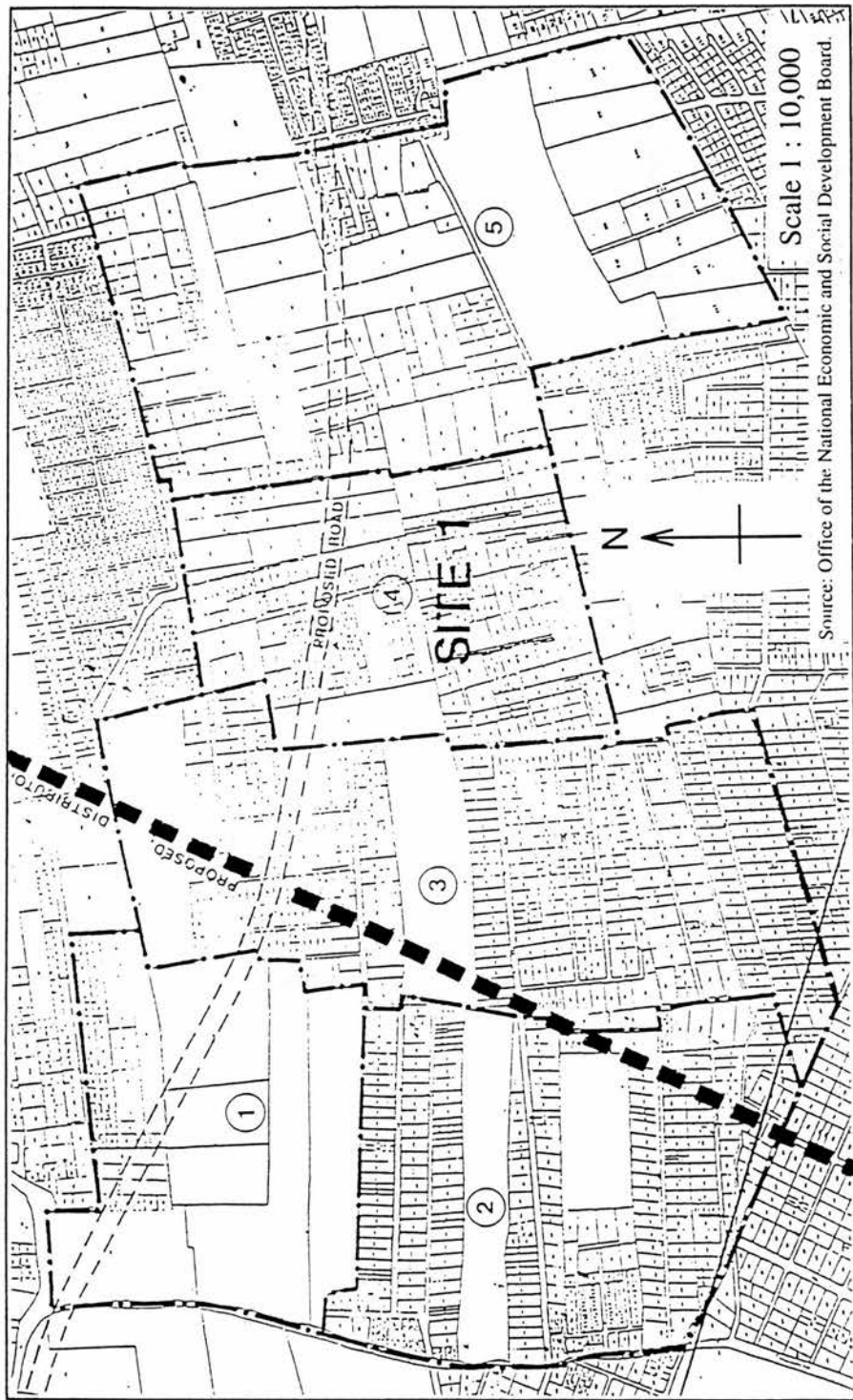


Figure 2.10 Land holdings of proposed 'Site 1'.

As the rest of the first section of the B2 Road will be implemented by the land expropriation method with funds that have already been allocated by the Government and the BMA, this will not encourage the Site 1 landowners to accept the land readjustment approach. The feasibility of land readjustment in the Site 1 is therefore quite uncertain at this stage, but in the Site 2 area it is most promising.

Site 2

The location of the Site 2 area is on the proposed Rattanakosin Sompoch - Nimit Mai Road (or the second stages of the B2 Road) in Bang Khen district. The site is approximately 7 km east of the Phahon Yothin Road and about 5 km north of Ramintra Road. The study area covers 585 rai or 96 hectares; there are some fruit orchards and most of the land is currently being used for rice farming (Figure 2.11). A direct supply of electricity from the Metropolitan Electricity Authority of Thailand (MEA) is the only facility available in the area. There is no water supply from the Metropolitan Waterworks Authority of Thailand (MWA), no municipal drainage system and no sewerage system. Public transport is also not available in the area. Although Site 2 area is outside the designated investigation area for the first section of the B2 Road, it is still a good study area because it provides a contrast to the Site 1 area, and is an appropriate site to illustrate land readjustment as a technique for converting rural land to urban subdivision land and/or building plots.

In February 1994, the SOFIE II team valuation consultant, led by Dr Nopant Tapananont, made a draft assessment of the financial viability of a land readjustment project for the Site 2 to implement the draft road layout and land allocation plan presented to NESDB. The land was valued at an average of Baht 3.47 million per rai before the project and Baht 8.91 million after land readjustment. The cost of the land readjustment project was estimated at Baht 328 million, an approximate estimate that included the cost of land filling and infrastructure construction but excluded the cost of interest on the project loan. These valuation and cost estimates indicated that the overall result of the land readjustment project for the landowners would be that they would lose about 34 per cent of their land area but have their rural land converted to serviced subdivision land and building plots with a 157 per cent increase in its unit value so that they would obtain a net land value gain of about 69 per cent from the project over one year. The project would therefore be financially viable.

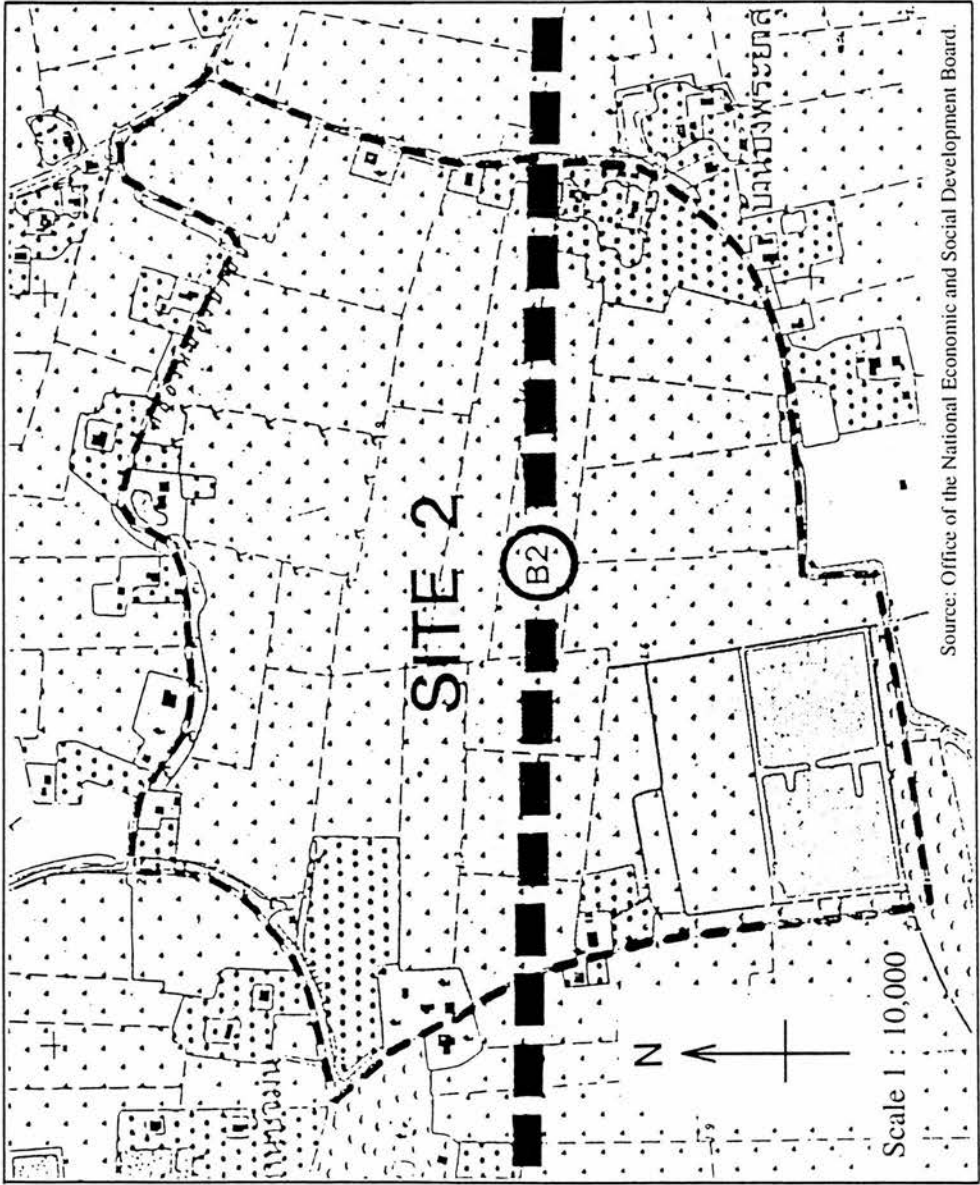


Figure 2.11 Existing conditions of proposed 'Site 2'.

As the land readjustment project for Site 2 would provide every parcel and plot with a public road access it would convert them from 'blind land' suitable for rural use into urban development land suitable for subdivision and building development. This physical conversion of land will make it more usual, more valuable and more marketable. Such a land readjustment project would be attractive to the landowners and it should be acceptable to them as soon as they are satisfied that there will be fair sharing of the project costs and benefits and that its implementation will be managed efficiently. Because the area north of Ramintra Road is developing rapidly, the Site 2 land is 'ripe' for suburban housing development.

In summary, land readjustment, in SOFIE I, is eventually regarded as a crucial tool for supporting the Seventh Plan implementation at national, regional and local government bodies in Thailand. The conclusion from the feasibility study of the SOFIE II is that there are more supporting potential of landowners in the Site 2 area than in the Site 1 area. In the research, the Klong Toei project has been commercially developed with a number of retail shops situated along the main roads (eg Sukhumvit 55 Road, Sukhumvit 63 Road) and the principal aim of the project is to apply land readjustment for rearrangement of land use. In the Lad Krabang project, most land parcels are deserted rice fields and lack of urban facilities, therefore, the aim of the project is to apply land readjustment for opening up 'pocket land'.

Chapter 3

APPLICATION OF LAND READJUSTMENT IN THAILAND

3.1 INTRODUCTION

In chapter 3, the application of land readjustment in urban areas of Thailand is examined. The chapter is presented in seven main parts. The first part outlines the possible application of land readjustment for the urban planned development in Thailand. The second part shows conditions for successful and efficient application of land readjustment. The third part explores the current laws related to land readjustment. The fourth part deals with the potential of landowners for supporting land readjustment in Bangkok. The fifth part reviews current techniques applied for urban land readjustment while the disadvantages of current urban land readjustment techniques are investigated in the sixth part. The final part proposes a new schedule for urban land readjustment in Bangkok.

3.2 THE POSSIBLE APPLICATION OF LAND READJUSTMENT FOR URBAN PLANNED DEVELOPMENT IN THAILAND

It has been discovered that there is great interest in Thailand in applying land readjustment for urban planned development. The subject is being studied by various concerned organisations such as the Asian Institute of Technology (AIT), Chulalongkorn University (CU), the National Institute of Development Administration (NIDA), the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), DTCP, NHA, BMA, NESDB, and JICA experts in Bangkok. Generally speaking, there are several approaches to land readjustment that

are being widely applied in many developed and developing countries. These can be summarised as follows:

- (1) The application of land readjustment for 'accommodation of existing rights (avoiding eviction)'

Those who have small pieces of land and could prefer not to sell their lots for a land development project, but would like to stay in the project area, can be accommodated in the project area via the land readjustment process.

- (2) The application of land readjustment for 'consolidation of a development area'

Small pieces of land which were isolated and scattered throughout the development area can be consolidated into a comprehensive development area through the technique of land readjustment. This approach is relatively useful for land developers and can be used as a machinery to avoid land development in a piecemeal fashion which requires higher capital investment. By this approach, lots can be utilised more efficiently.

- (3) The application of land readjustment for 'consolidation of government land'

The government can buy land in advance in the area of planned roads. It can then consolidate these small land parcels into one right of way, for the road, using the technique of land readjustment by transferring the location of existing lots.

- (4) The application of land readjustment for 'enhancement of donation'

Co-operative development has been conducted for many decades in Thai culture by the donation of land for the construction of temples, schools, hospitals, roads, and other public facilities. Therefore, landowners who own land outside the project area (eg the right of way) can donate their land to the government through the process of transferring lot portions via land readjustment.

- (5) The application of land readjustment for 'fair land acquisition'

All owners of land who will benefit from the construction of the planned road have to sell some portions of their land to the government. Transferring and combining portions of lots via the land readjustment technique make this possible, resulting in 'fair land acquisition'.

(6) The application of land readjustment for 'opening up pocket land'

The landowners, whose land can not be accessed by roads, can share costs and the land for the accessibility of roads to open up land-locked parcel or pocket land.

(7) The application of land readjustment for 'rearrangement of land use'

With the help of this land readjustment technique, rearrangement of land use can help meet the requirements of landowners who would like to improve a chaotic existing pattern of land use in their neighbourhood. For instance, those who would like to continue farming are transferred to the newly planned agriculture area. Those who would like to run a commercial business are located in the newly created commercial areas.

As well as these various approaches to land readjustment, there are additional cases for possible application of land readjustment in Thailand suggested by a JICA expert (JICA, 1989). These include housing, road improvement, creation of new space, and other infrastructure improvement; for example,

- construction of flood control structures,
- new town development (eg government town, science town),
- new town projects implemented by public authorities,
- reorganising the network of neighbourhood roads (lane).

3.3 CONDITIONS FOR SUCCESSFUL AND EFFICIENT APPLICATION OF LAND READJUSTMENT IN THAILAND

Archer (1987) pointed out that although land readjustment has significant advantages over the usual land development process, the advantages are potential rather than automatic and they have to be achieved by the appropriate application of the technique. The technique has to be used selectively and each land readjustment project has to be technically, legally, physically, financially, and administratively viable and furthermore has to be efficiently implemented.

Technically speaking, the utilisation of land readjustment in Thailand is viable because implementing agencies like the NHA can design and manage land readjustment schemes. The nature of the work is not so much different from the nature of the present function of the NHA. The NHA is currently considered to be the only public agency in charge of distributing land and housing to the low and middle income families.

From the legal point of view, in order to implement an efficient and successful land readjustment project, the government has to establish the law, such as Urban Land Readjustment Act, to regulate the preparation and the implementation of the land readjustment project.

Land readjustment is physically viable because the selected land will need to be 'ripe' for development. This means that one or more of the adjoining land holdings should have a public road frontage, that water supply and electricity mains should be nearby and the area should also have potential for profitable subdivision.

Land readjustment is politically viable because it is acceptable to the majority of landowners, whose land holdings are converted into readily saleable home sites with a significant increase in their market value after costs. These landowners can counter the political pressure against pooling that might come from any minority of 'holdout' landowners in the project area (Archer, 1982). To a certain degree, support of at least

50-60% of landowners is a legal requirement in some countries but support of 80% or more of landowners is likely to guarantee the success for their projects.

Land readjustment is financially viable since it has not only provided government with the funds necessary for building infrastructure, but has been quite profitable for the participating landowners. It has been a kind of land development done in public-private partnership in which both partners have gained. In addition, no cash compensation is paid to the landowners, and the working capital required can be borrowed as a short-term bank loan and then recovered promptly by the sale of some of the sites.

Land readjustment is administratively viable as consultant professionals can be hired to design and manage the projects, and because it can be learned by beginning with simple pooling projects. Well-trained appraisers are also required and the availability of these may therefore be one of the preliminary keystones to the whole land readjustment effort (Doebele, 1982).

In brief, the utilisation of land readjustment in Thailand is viable in both private sector and public sector, especially where implemented by an organisation such as the NHA which has gained experience in providing affordable land and housing for the low and middle income citizen for more than two decades.

3.4 THE POSSIBLE APPLICATION OF LAND READJUSTMENT FROM LEGAL VIEWPOINTS

Where land readjustment projects are implemented, there is normally registration which binds the landowners to participate. In some countries, legal support for land readjustment is stipulated by related legislation such as the Fundamental Land Law in the case of Indonesia; in others there are specific legal systems for land readjustment

such as in Germany, Taiwan, South Korea, Japan and Sweden. In Thailand, there has no law concerning urban land readjustment. However the possible use of land readjustment has very considerable critical legal implications. These can be summarised as follows:

(1) An implementation of land readjustment without any legal basis

Land readjustment can be applied in Thailand without any legal basis since the technique of land readjustment does not violate any existing Laws or Acts imposed on Thais, for example, Announcement of the Revolutionary Party No. 286 (Law on Land Allocation). Therefore, the government agency and land developer can conduct the land readjustment at will without the backing of any law. The possible applications of land readjustment by this method consists of:

(i) Negotiation type project within the framework of existing laws

Although no law has yet been enacted, the land readjustment process could be implemented by negotiation with landowners who can see mutual benefit in joining together in a co-operative project.

(ii) Donation type project

Co-operative development is traditional in Thai society in the form of donation of lands for the construction of roads, schools, hospitals, temples, police stations, and other facilities. It is deemed to be one of the effective methods for the application of land readjustment in Thailand.

(iii) Land readjustment through other existing laws

It may also be possible to implement land readjustment through other existing laws, such as the Agricultural Land Consolidation Act of 1974, the Agricultural Land Reform Act of 1975, and the Land Development Act of 1983 (Bothdumrih *et al.*, 1988). JICA (1989) pointed out that, in Japan, the current Japanese land readjustment law was derived from the Arable Land Readjustment Law.

(2) An implementation of land readjustment by means of General Plan under the
Town Planning Act, 1975

Item (5) of section 17 in Chapter 3 ('Preparation and making of a general plan' contains 'policy, measure and method of implementation of the general plan') (DTCP, 1975). Consequently, the land readjustment process, an implementation method, may be authorised under the Ministerial Regulation governing the enforcement of a general plan.

(3) An implementation of land readjustment by means of Specific Plan under the
Town Planning Act, 1975

Item (5) (J) of Section 28 in Chapter 5 ('Preparation and making of a specific plan') provides authority for 'Other matters, as may be necessary, in accordance with the objective of the specific plan' (DTCP, 1975). It can be interpreted that the implementation of land readjustment can be done or not done in accordance with the purpose of the specific plan.

(4) An implementation of land readjustment by means of amending the
Town Planning Act, 1975

There are still no clear points in the existing Town Planning Act of 1975 concerning the implementation of land readjustment since the Act only provides general authority which is not enough for any government body to implement the land readjustment. Therefore, such an amendment is recommended within the existing Town Planning Act especially in the part dealing with Specific Plan.

(5) An implementation of land readjustment by means of establishing a New
Urban Land Readjustment Act

In order to implement the successful land readjustment project, the Government have to establish the legal and the administrative machinery to authorise, regulate and oversee the preparation and the implementation of the land readjustment projects. It seems worthwhile to try to find a legal basis for implementing land readjustment in



specific planning or in the implementation of the Agricultural Law Reform Act or similar laws since utilisation of effective land readjustment will not be fulfilled without the support of the Act.

It is necessary to admit that the adoption of land readjustment in Thailand will involve more than passing an urban land readjustment Act and undertaking land readjustment projects. The legal and regulations will also need to be supported by a central government administration in order to guide and supervise the activities of the various land readjustment implementing bodies. Although the existing laws could be used for the adoption of land readjustment in Thailand, it would be preferable to enact the new Act to regulate and authorise the preparation and implementation of land readjustment projects by several government agencies for a range of purposes.

3.5 POTENTIAL OF LANDOWNERS FOR SUPPORTING LAND READJUSTMENT IN BANGKOK

The difficulties of land assembly for orderly urban land development in both the private and government sector have been mentioned; there is a requirement for an alternative approach such as urban land readjustment. There is also the possibility of getting majority landowner support for pooling projects. While the difficulties of land assembly for urban land development are due to the withholding of their land for selling by numerous landowners, the majority of them could be led to involvement in pooling projects when there is the possibility of their gaining a considerable mutual increase in the market value of their land. There are a number of land development situations in Bangkok Metropolis where land readjustment could be used both to improve land development and to give the landowners a significant net gain in land value.

A first possible application of land readjustment in urban areas of Bangkok Metropolis would be urban land readjustment projects performed to finance the provision of special infrastructure works, such as fixed bridges, that are needed for some land subdivision projects. Many canals in Bangkok impede the urban development of land parcels by obstructing their road access. The bridges are comparatively expensive to construct and a single landowner or small group of united landowners usually cannot afford to pay for a bridge; few bridges are therefore constructed. Under the circumstances, it would be possible to formulate an urban land readjustment project to construct the bridge and to subdivide and provide all the land that would gain benefits from the bridge, and could also share the cost of the bridge. The landowners who could surmise a significant increase in the value of their land - after realising their share of the project costs, including the cost of the bridge - would be liable to support the project.

A second possibility for landowners to support an urban land readjustment project is the construction of a new public road in the urban fringe land in order to connect to a nearby urban road network. The construction of the road will considerably increase the market value of the land parcels that it cuts through. Consequently, this new access and land value increase would be extended in-depth to the adjoining rear land parcels on both sides of the road. By bringing these land parcels into development through an urban land readjustment project, all the landowners would benefit from the road and would therefore be potential supporters of the project. In the same situation, the public road authority could also gain indirect benefits by means of undertaking or initiating an urban land readjustment project in conjunction with its road construction work, so as to fulfil development in depth instead of ribbon development, and to recover part or all of the cost of the land acquisition and road works. When the road authority has to make a resolution between alternative public road projects, it could survey the potential landowners in each proposed road area who are ready to co-operate and support the construction of the road.

A third possibility for landowners to assist with an urban land readjustment project is by involvement in unifying lands which are separated from an existing public road by other land parcels that a single landowner cannot afford to purchase, or cannot negotiate the purchase of a portion of the land, in order to construct a connecting road. In this situation, a government agency such as the NHA can play a major role in purchasing one or more land parcels with the road frontage, and then formulate an urban land readjustment proposal for combining this land with the land parcels behind it for their unified servicing and subdivision (Archer, 1992). It is evident that the project would not only provide road access but also that the land values for the rear land would increase.

3.6 REVIEW OF CURRENTLY AVAILABLE TECHNIQUES FOR URBAN LAND READJUSTMENT IN BANGKOK

As land readjustment has happened and has made good progress in many parts of the world, it is revealed that there is great interest in Thailand in land readjustment techniques, and in fact several feasibility studies conducted by various government agencies such as the DTCP, NHA and BMA have employed the techniques. As a common practice, the three-step process of preparation of proposal, project preparation and project implementation for carrying out urban land readjustment can be summarised and is shown in Figure 3.1. Based on the experience of other countries (eg Germany, Japan, South Korea, Taiwan), it is very probable that land readjustment can have a potentially significant impact on the availability of urban land in Bangkok Metropolis and provincial cities of Thailand.

In this section a wide variety of techniques and associated technology concerning problems and feasibility studies of land readjustment in Bangkok Metropolis will be reviewed. The techniques can be grouped into two; the first group deals with the

current techniques applied for data capturing for land readjustment, and the second deals with the current urban land readjustment techniques.

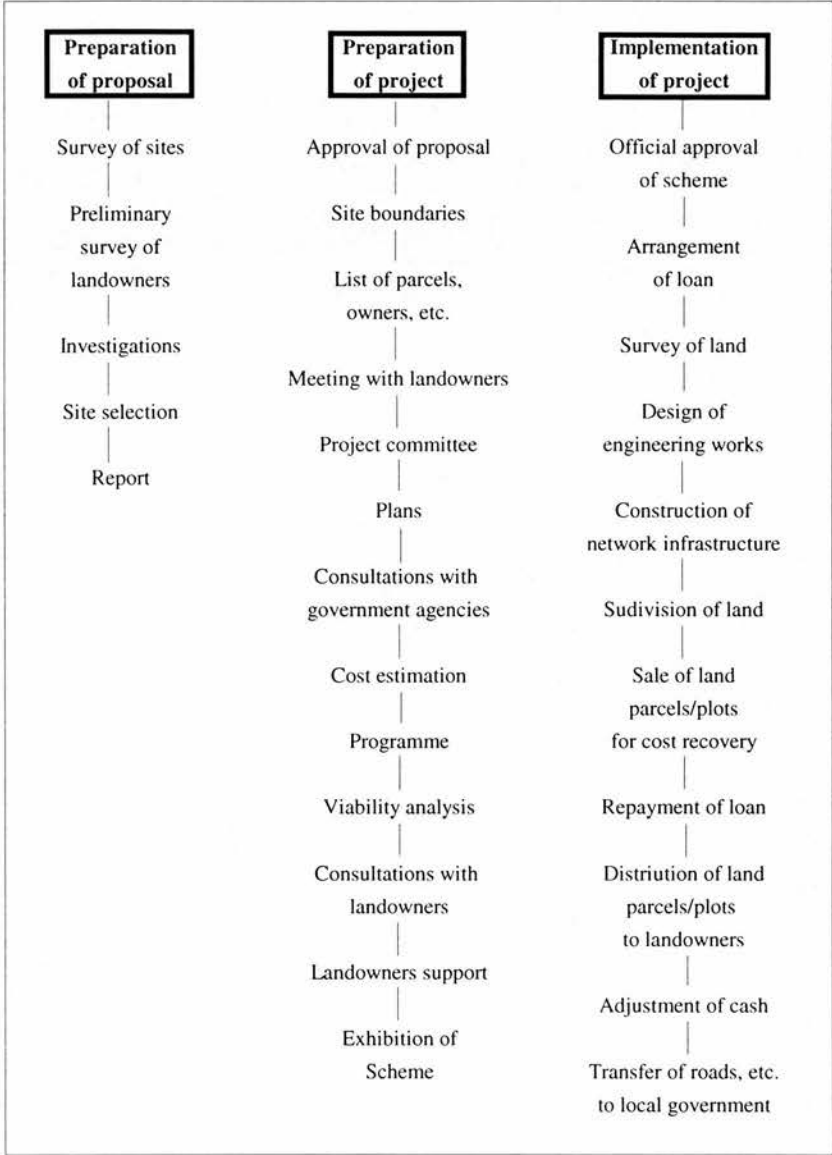


Figure 3.1 Proposed standard procedure for preparing and implementing urban land readjustment in Thailand.

3.6.1 The current techniques applied for data capturing for urban land readjustment

The current techniques applied for data capturing for land readjustment conducted in Thailand by city planners are completely dependent on data produced by

related government agencies (eg the Department of Police, BMA, DOL, DTCP). The DOL is responsible for land administration, land development, cadastral surveying and land registration in Bangkok and urban areas throughout Thailand. While the DOL is able to carry out its land-related responsibilities it does so less effectively because of the poor state of the urban cadastre and urban mapping. As a result, the existing urban and suburban cadastral maps produced by the DOL are often out of date, cluttered in detail, incomplete, or at too small a scale for city planners to generate the urban land readjustment (Figure 3.2). The fundamental cause of the current problem has been the inability to update cadastral maps to keep pace with the rapid urban growth rate of Bangkok. The problem is particularly evident in many government organisations which are responsible for city planning in Bangkok, where the rapid urban growth rate means that maps are soon in need of revision. Chanlikit and Kirby (1993) point out that the maps are considered to play a vital role for city planners whenever land readjustment is taking place.

In the Bangkok Metropolis, access to fundamental land ownership and land parcel information is made more difficult because of the lack of basic cadastral index maps. Furthermore, a lack of up-to-date, reliable, good quality urban cadastral maps has created problems for other government departments and local authorities that are involved in land management, planning and the provision of services. In many cases these departments and utility authorities have endeavoured to produce their own urban maps to satisfy their specific needs. As a consequence, there has been duplication of work and wasted public resources (DOL, 1985).

At present, the city planners are obliged to take it for granted that the existing cadastral maps are more or less accurate enough for executing the urban land readjustment procedure. The JICA (1989) report on city planning in Thailand also disclosed that base maps and title deeds prepared by different agencies were inaccurate, sometimes to a significant degree. This inaccuracy resulted in difficulty in replotting design.

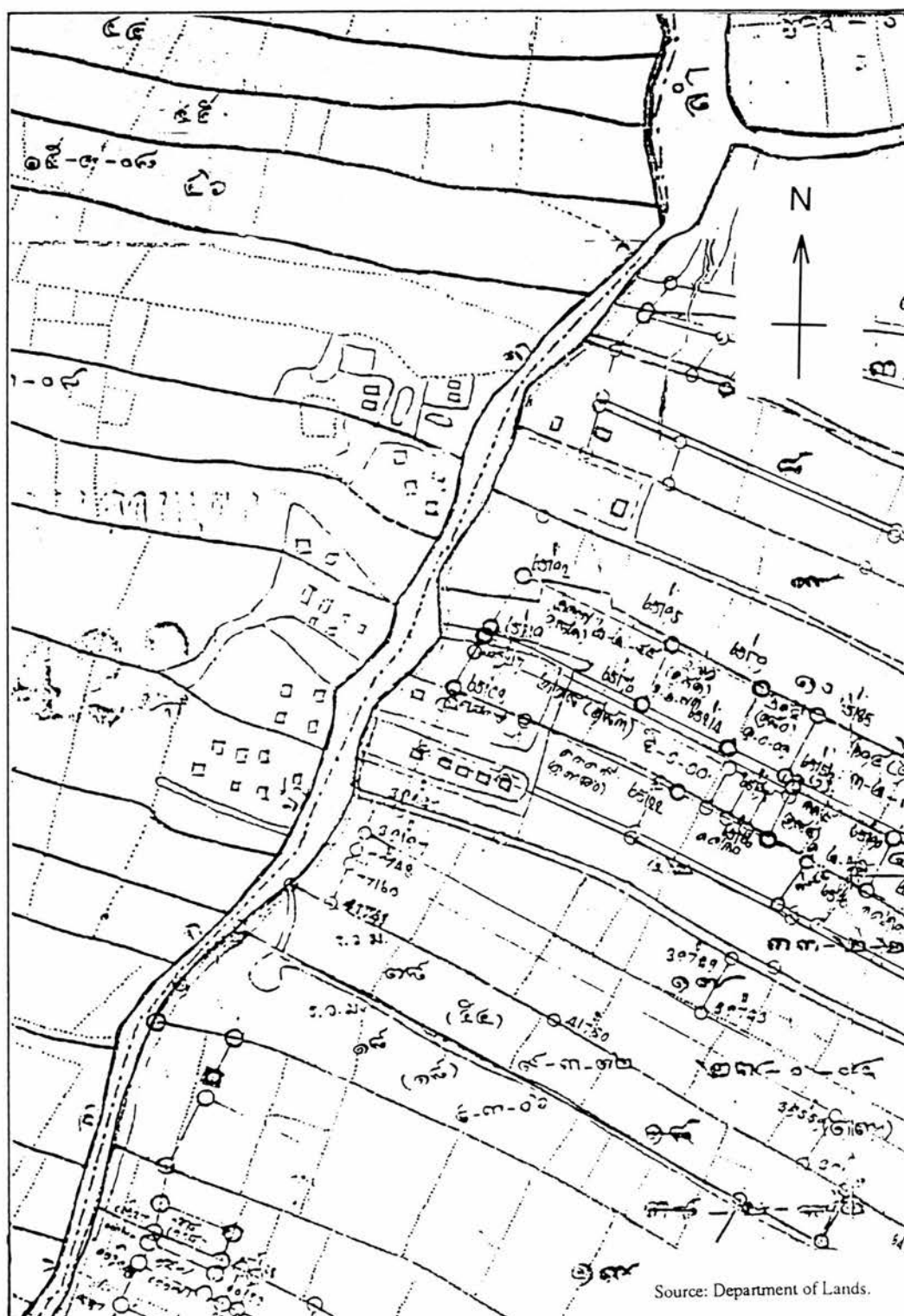


Figure 3.2 A typical cadastral map of approximately scale 1:4,000 in Lad Krabang district, Bangkok.

In many cases, the city planners also discovered that neither cadastral nor other large scale maps existed for the areas of interest. Therefore, the planners had no alternative but to utilise other existing maps for generating urban land readjustment, for example, a city map of scale 1:12,500 - 1:20,000 and a topographic map of scale 1:50,000 which were produced by the Royal Thai Survey Department (RTSD). The maps were later enlarged from medium to large scale maps (eg a scale of 1:2,000) by means of a simple plotting tool like a pantograph or a commercial photocopier. The pantograph and the photocopier are normally not considered to be precision equipment for reduction or enlargement of maps since they cannot maintain the accuracy of the original maps, either in area or in length.

There also does not exist a large scale building map, considered to be an indispensable tool for city planners whenever urban land readjustment is being implemented. Generally, the current building map for duplication of buildings is produced by means of utilising a cadastral map as a base map and superimposing it on the top of a rectified or an uncontrolled aerial photograph which had approximately the same scale. It was discovered that relief displacement still existed by this method and the map became even worse when the uncontrolled photograph was introduced in the duplication process.

In addition, manual techniques of map analysis are still popular among city planners; the techniques are considered to be extremely labour intensive and time consuming. It is revealed that digital maps have also been introduced recently by the DTCP as a part of data capturing in the feasibility study of land readjustment process (Table 3.1); they are however provided much more in terms of display functions than as an analysis-oriented approach.

Apart from the digital data produced in the Klong Toei district for the Bangkok Land Information System (BLIS) pilot study, there is an absence of existing accurate, large scale digital map base data within Bangkok Metropolis. As such, to build up this

digital map base over Bangkok will be an extensive, costly exercise, especially when the required attribute data, such as house/building number, owner's name, are included. It is vital for the future of the BLIS that this map base be initially constructed on an accurate coordinate system as established by the RTSD and utilised by the DOL. In fact, the only accurate Universal Transverse Mercator (UTM) based, 1:1,000 scale, hard copy plans existing for Bangkok are produced by the DOL but do not have the street furniture, pavements or buildings which are required by the utility agencies or other users (Mathieson, 1992).

Table 3.1 A list of existing maps within the Bangkok Metropolis area.

Agency	Type of map	Map scale (1:)
BMA	Digital cadastral map	1000
	Digital building map	1000
	Hard copy city map	4000
	Hard copy city map	10000
DOL	Hard copy cadastral map	1000
DTCP	Digital cadastral map	1000
	Digital building map	1000
NHA	Hard copy cadastral map	1000
	Hard copy building map	1000

In brief, the study of urban land readjustment carried out by several government agencies such as the DTCP, NHA and BMA begins from drawing maps such as topographic map 1:50,000 and city map 1:12,500 - 1:20,000 of the area selected for studying an overview of the project in the stage of site selection (Figure 3.3).

It is necessary for the implementing body (eg the NHA) to study the project more carefully when a land readjustment project is to be prepared. As a consequence, the map based on the present or existing condition of the area is drawn on a scale of 1:1,000 to 1:2,500.

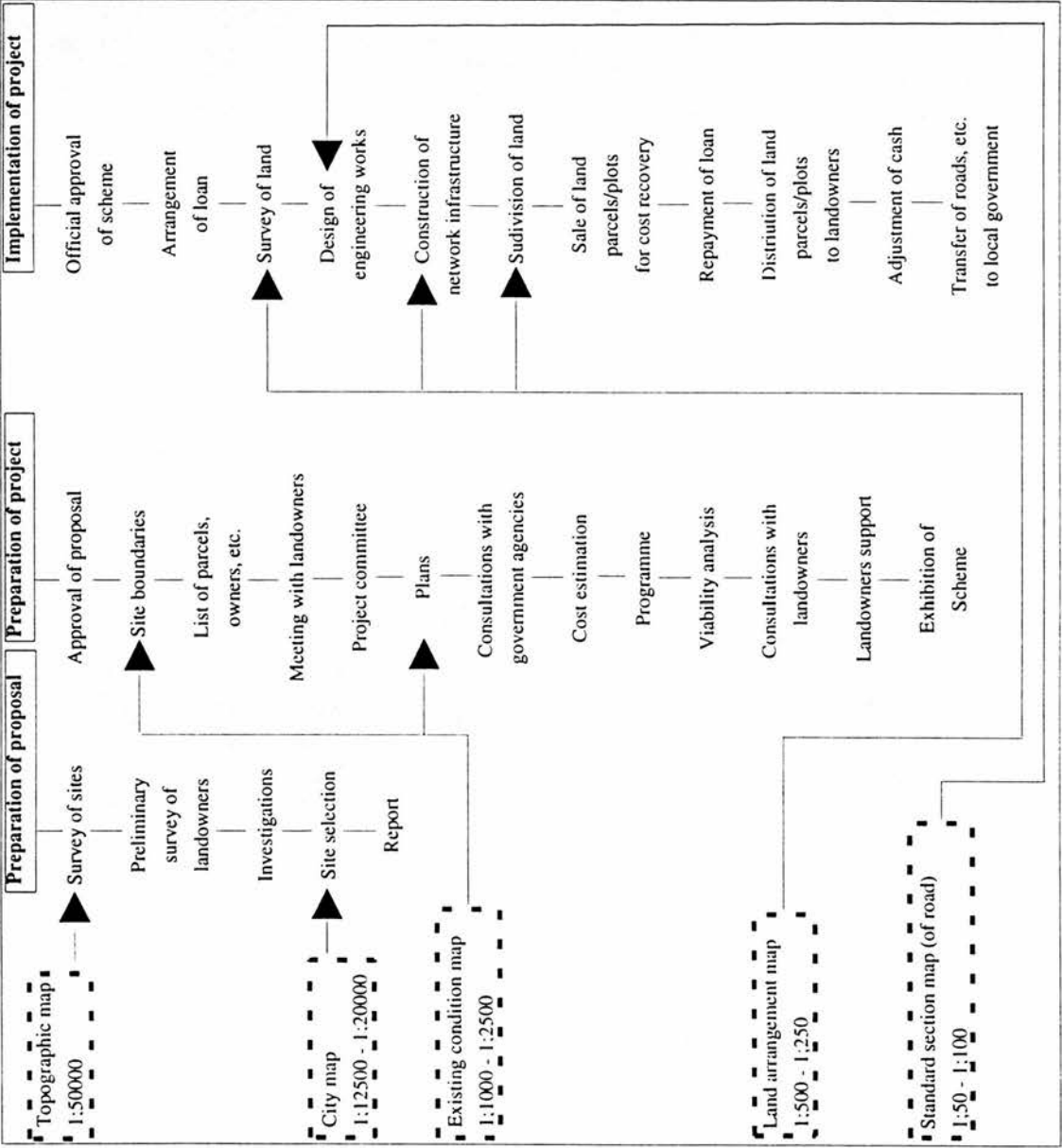


Figure 3.3 Utilisation of various maps in the urban land readjustment procedure in Thailand.

This map is used also for various kinds of studies that come afterwards but it is mainly used for the creation of the key concept plan and the master plan. The study will be later carried out in order to check the details of the area for the project implementation when the previous study has been completed, and it has been judged that the implementation of a land readjustment project is possible. The study map of the area in this stage will be drawn on a scale of 1:250 to 1:500 and also on a scale of 1:50 to 1:100 for designing of engineering works such as a standard section map of a road.

3.6.2 The current urban land readjustment techniques in Bangkok Metropolis

The feasibility studies of urban land readjustment projects have been conducted since early 1992 in Bangkok Metropolis areas by different government agencies; the agencies involved in the projects are the DTCP, NHA, and BMA. Lee (1982) supports an idea that urban land readjustment is an integrated land reform that, because of its complexities, requires not only large administrative expenditures and labour, but also technical exchanges and co-operation between government agencies and landowners. There are common steps that the DTCP, NHA, and BMA carry out through the urban land readjustment which can be generalised as follows:

- site selection;
- site boundary;
- list of parcels, owners and valuations;
- plan of road layout;
- infrastructure plans;
- cost estimation;
- replotting plan;
- list of new land parcels and valuations.

In this thesis, these common steps are also applied in the proposed schedule for urban land readjustment. Therefore, some steps will be explained in chapter 3, section 3.8; others will be described in greater detail in chapter 4, chapter 5, and chapter 6.

The Department of Town and Country Planning

It can be said that the Department of Town and Country Planning deserves the credit for being one of the first pioneering agencies in this field. A pilot urban land readjustment project, on Rama 9 Road, has been conducted by the DTCP since 1992 with the notion that current urban functions and industries should be dispersed from the existing central business district. The DTCP made a resolution to exercise computer systems such as computer-aided design (CAD), and commercial software packages for the quantitative and qualitative improvement of the project. Besides, the street value evaluation method is applied for replotting plan and land evaluation in the financial planning process.

The National Housing Authority

The National Housing Authority launched its urban land readjustment project in early 1992 in the western side of the Lad Krabang Community Housing Project, Lad Krabang District, Bangkok Metropolis. Most graphical data capturing procedures have been done through manual processes. A personal computer is involved in the process of data manipulation and computation of financial plan. A market price comparison method is applied for land evaluation in the financial process. Furthermore, there are two development scenario approaches: the first deals with the full development scenario, which includes the cost of land filling for the whole project area; the second involves partial landfill, in which case the construction cost would be significantly lower.

The Bangkok Metropolitan Administration

The Bangkok Metropolitan Administration has been involved in the urban land readjustment since early 1992 as mentioned in chapter 2, section 2.9.3. It can be said that graphic data have been intensively introduced by a manual approach for the feasibility studies of urban land readjustment in SOFIE I, and SOFIE II. The replacement value and market price comparison method are also adopted in the SOFIE II, site 2, with the help of a written program, the computer assisted mass appraisal (CAMA), through multiple regression analysis in the financial plan process.

3.7 THE DRAWBACK OF CURRENT URBAN LAND READJUSTMENT TECHNIQUES IN BANGKOK

The adoption of land readjustment as a new technique for urban land readjustment in Bangkok Metropolis should commence by classifying and recognising the principles of land readjustment, and then considering these principles together with the existing system of urban land development in order to design a suitable urban land readjustment system. This system should combine standard procedures to be followed by the selection, preparation and implementation of all urban land readjustment projects. As far as the urban land readjustment is being applied by the DTCP, NHA, and the BMA, some drawbacks of the current techniques can be encapsulated as follows:

- Large-scale city maps of 1:4,000 sponsored by the JICA in 1988 have not been covered all the Bangkok Metropolis area; they are simply available in the densely urbanised areas. Beyond that, the maps, sponsored by the JICA in the late 1988, covered all the areas are of scale 1:10,000 which are considered not to be suitable for site selection and location of the urban land readjustment project.

- Large-scale cadastral line maps of scale 1:1,000, produced by the DOL, are in a hard copy type (duplication of 1:1,000 scale of rectified aerial photographs) and unobtainable for all the area. Whenever the city planners do require a larger (or smaller) scale than the existing one (1:1,000), they have three practical methods to cope with the scale change. The first is enlargement of the existing map by means of a commercial photocopier. This method is deemed to yield extensive error because the photocopier cannot exclude distortion at any required scale. The second is manual digitisation by means of digitisers which is considered to provide a better result than the first method. Petrie (1990) points out that manual digitisation of point and line data contained on a map can provide an accuracy (root mean square error, RMSE) of the final positional coordinate values in the order of $\pm 100 - 250$ microns ($0.10 - 0.25$ mm), equivalent to ± 0.10 to 0.25 m at 1:1,000 map scale. The last method uses scanners; the results of standard tests suggest that scanners are 7 times faster than digitisers for contours and at least twice as quick for planimetry (Burrough, 1994).
- There are also no large-scale maps such as for building, vegetation type, or facility network (eg electricity, telephone, water supply) which are regarded as an indispensable tool for preparation and implementation procedure in the urban land readjustment process.
- In general, the current techniques are bound to a manual approach and there is no automatic linkage between graphic and non-graphic data. This brings about inaccuracy and a delay in spatial analysis, financial computation, and replotting procedure because of the complexity and the tremendous quantity of data.
- Lacking good database management systems (DBMS) for non-graphic data results in getting unreliable and wrong results, as well as difficulty in retrieving and updating the data during processing of financial plan.

- As the Japanese urban land readjustment model has had influence on the urban land readjustment model carried out by the DTCP, the 'street value evaluation method' is chosen as a method which can satisfy financial plan and the replotting design in the urban land readjustment procedure. The street value is not expressed in monetary values but by the 'index', a relative value which is referred to as 'street value index'. As land values are expressed in index numbers, values are easy to compare as an increasing ratio of lots before and after the project, but the index numbers have also caused confusion. Moreover, different agencies have criteria to set their own standard of index values. The Japanese procedure reflects the Japanese situation of subsidised projects, complicated projects in built-up urban areas, and long project preparation and implementation times. In Thailand, urban land readjustment is completely new and the procedures should be designed to give the landowners full information so they can join the projects with confidence and with minimum uncertainty and risk.

3.8 A PROPOSED SCHEDULE FOR URBAN LAND READJUSTMENT IN BANGKOK

It will be clear from earlier material that land is considered to be mankind's most valuable resource. It is nowadays obvious that a land information system is a fundamental requirement for making decisions related to land development, land planning and land investment in both the private and public sectors. The system yields support to land management by providing information about the land (eg landowner, location of land), the resources upon it and the improvements made to it. The information curtails risk and uncertainty by helping to clarify and resolve problems. This situation is explicitly true in countries in the developing world where the rapid growth rate of population has placed pressure on land and at the same time a massive migration of people to cities and towns has led to the uncontrolled growth of urban centres causing insufficient housing, roads, schools, parks, scattered urban

and suburban sprawl. In Thailand there are also land subsidence and flood problems. The solution to these problems can be fulfilled by means of city planning which is needed in support of urbanisation. Government and private agencies must also plan some efficient land acquisition strategies in advance. Planning must be based upon knowledge, knowledge depends upon information, and information depends upon the method of survey and the manner in which its results are communicated. Land readjustment is one of the planning mechanisms which deals with these demands and provides a more efficient approach for land acquisition (Figure 3.4).

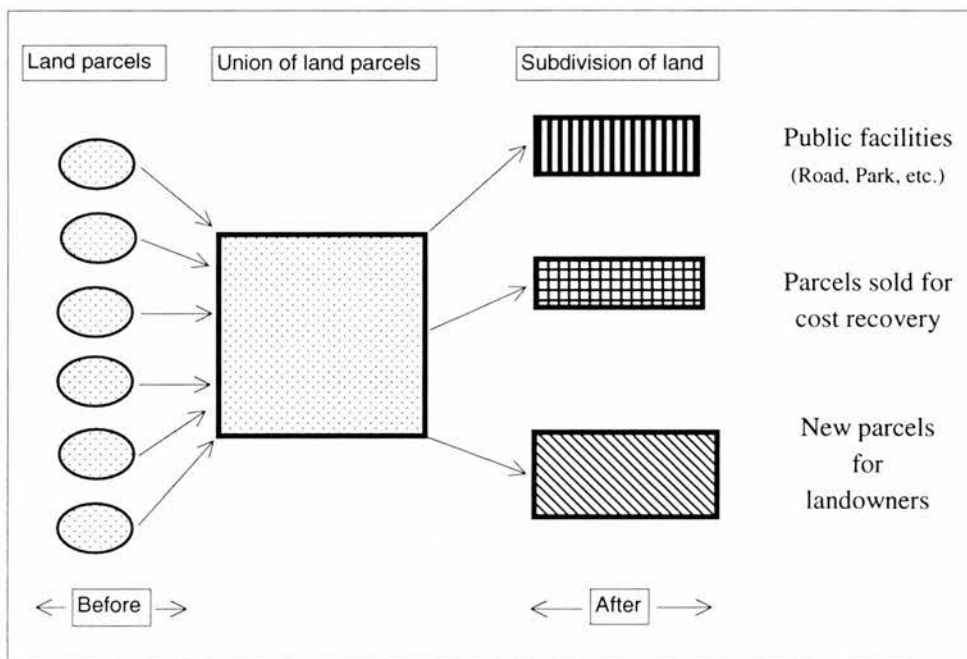


Figure 3.4 The mechanism of land readjustment.

A Land and Geographic Information System (LIS/GIS), as described in Appendix 3.1, is employed because it has great functionality to cope with the complicated tasks of capturing, storing, manipulating, analysing, and displaying large volumes of data which are in the same referenced coordinate system. Moreover, as is generally recognised, when these data have been input to a LIS/GIS, they can be easily manipulated and analysed in ways that would be too costly, too time-consuming, or practically impossible to do using manual methods.

This study attempts to provide the solutions to investigate the practicality and suitability of using LIS/GIS techniques to cope with the problems of urban land readjustment in Thailand. The following steps are required for undertaking the urban land readjustment in Thailand.

- (1) acquisition of existing maps and aerial photographs;
- (2) site selection and boundary;
- (3) preparation for field work;
- (4) reconnaissance and field identification;
- (5) mensuration by GPS;
- (6) heighting;
- (7) aerial triangulation;
- (8) digital mapping;
- (9) field completion;
- (10) classification of land use, building type, vegetation cover type;
- (11) database design;
- (12) layout of master concept plan;
- (13) proposed model for urban land readjustment;
- (14) cost estimation;
- (15) replotting design and plan;
- (16) list of new parcels and valuations.

The steps which are mentioned above will be discussed in greater detail in chapter 4, chapter 5, and chapter 6.

LIS/GIS are recognised as an amalgam between a computer technology and a land management tool. City planners are placing greater emphasis on having access to accurate, land related information to assist them in formulating resource policies and urban land readjustment. Map and attribute data are resources used daily for delivering and managing public services, and setting public policy in all local governments across the nation and throughout the world. Before LIS/GIS technology was available, traditional information systems were used to process location-related

data and produce reports in tabular form. These reports had meaning when they were used with a map as a reference (Huxhold, 1991). Nowadays, the LIS/GIS technology contains the map information in digital form. However, the attribute data and the map data can be processed together as a single product with little manual intervention.

In Figure 3.5, graphic data (small and large-scale thematic maps, rectified aerial photographs, and diapositive and paper print types of aerial photograph) can be converted into digital form by three standard methods: by using analytical stereoplotters; digitisers; and scanners. The digital data are later sent to a GIS package. In addition, the digital XYZ coordinates can also be obtained by means of conventional total-station surveying equipment - the coordinates are sent to the GIS package for producing large-scale digital map (eg park facilities map of scale 1: 300) which will be used in the implementation of plan. In the thesis, there is no attempt to get involved in the implementation process of urban land readjustment; therefore, the utilisation of traditional total-station surveying equipment has to be ignored. For this reason, the data capture for LIS/GIS can be done by means of the AP190 analytical stereoplotter, and a digitiser, as shown in Figure 3.6

To begin with, graphic data - such as paper print type of aerial photographs - are marked for ground control surveying. The accurate planimetric data are mensurated with the help of GPS receivers, and the height by using levelling. The coordinates are introduced into the AP190 stereodigitiser's environment to generate accurate three-dimensional models for digital mapping. The digital maps are later transferred to ARC modules.

Also, graphic data - such as thematic maps (eg soil map, geologic map) and rectified aerial photographs with cadastral details - are converted into digital forms by way of a digitiser. Moreover, the non-graphic data (eg landowner's name, land market value) are also designed as parcel-based information and executed in the RDBMS environment.

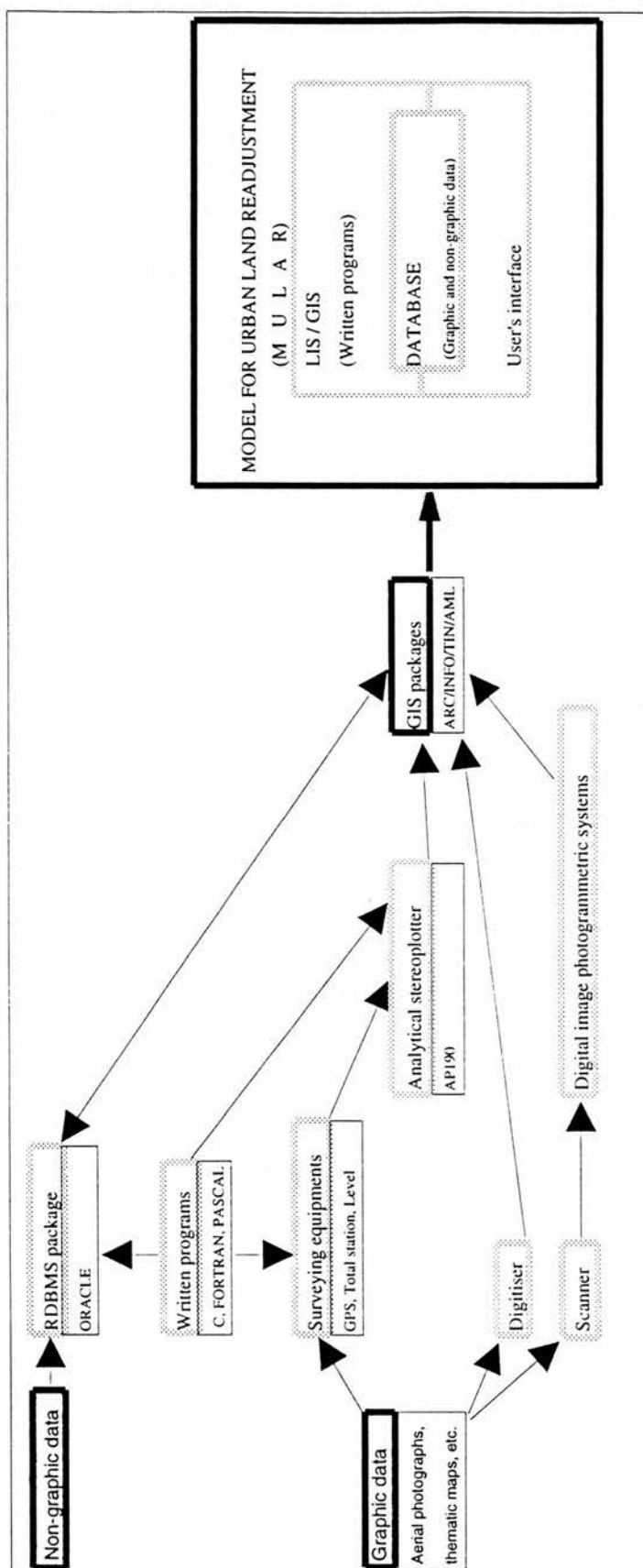


Figure 3.5 A rationale model for urban land readjustment.

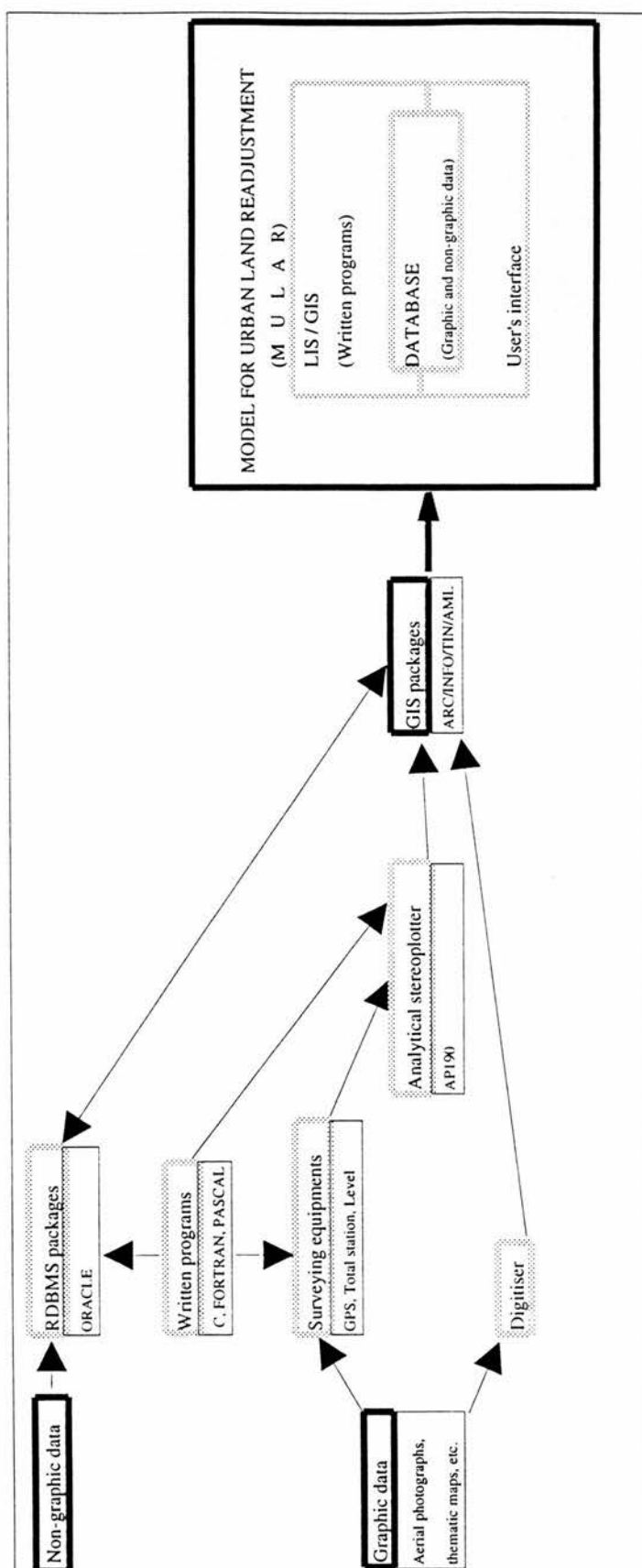


Figure 3.6 A proposed model for urban land readjustment (MULAR).

The LIS/GIS package - ARC/INFO - is introduced to the systems for a number of reasons: it is a flexible and powerful software package; it is one of the market leading systems which provide several platforms (eg PC's, workstation, and servers); and specific GIS applications can be developed by using the Arc Macro Language (AML). Furthermore, a highly structured language such as C and FORTRAN can also be used in the systems for the programming requirements.

The task of the LIS/GIS professional is to integrate those information systems used by the different sections in an organisation and to make users more effective in their working environments. The proposed model in the thesis is called MULAR (Model for Urban Land Readjustment) and has been developed to increase the performance of current urban readjustment applications. MULAR has a user-friendly interface so that a user can interactively and easily operate the requirement procedures, for example, a layout of master concept plan, or a replotting design. All the technical tasks are executed from series of pulldown menus. In the meantime, a user can access any ARC/INFO modules such as ARCEDIT, ARCPLOT, TIN through the system for further use. The MULAR system is composed of six basic functions - EDITING, ANALYSIS, QUERY, DISPLAY, PRINTOUT, and HELP - to accomplish the required tasks in the urban land readjustment process.

1. EDITING

Normally, data input and editing are carried out in the system with the help of the capability of ARC/INFO and ARCEDIT in order to generate graphic coverages which are utilised in the ANALYSIS options.

2. ANALYSIS

Building of topology and monitoring spatial analysis are automatically performed according to the design and land use planning details. Required modifications in the layout of master concept plan can be made interactively through the capability of the pulldown menu in the MULAR system.

3. QUERY

The fundamental GIS used has been the ARC/INFO system (version 6.1.1), and data related to land have been stored in the ORACLE (version 6.2) as an external hybrid approach (Figure 3.7). As the GIS database has developed, a variety of analytical and other work has been performed. SQL (Structured Query Language) is a relational database language being used in ORACLE. Among other things, the language contains statements to insert, update, delete, query and protect data (van der Lans, 1992). SQL can be used in two ways. First, interactively: an SQL statement is entered on the computer and processed for an immediate result. The second way is called embedded SQL where SQL statements are embedded in a program, written in another programming language (eg C or FORTRAN) to extend that language for use in the database access (Groff and Weinberg, 1990). Both graphic and attribute data related to land parcels can be easily queried through the SQL. Query results are normally displayed on the screen, saved to a file or sent to a line printer.

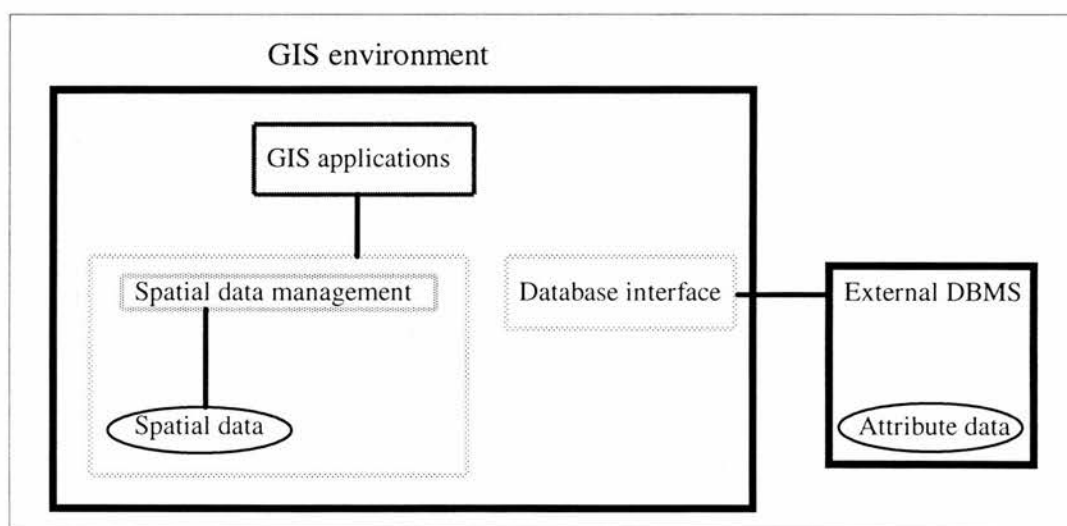


Figure 3.7 A type of GIS information architecture for external hybrid DBMS approach.

4. DISPLAY

The AML, a fourth generation computer language, has been used in the MULAR not only to control the operation of the system, but also to create a graphic output

which is either shown on graphics terminal or produce as a plot file which can be sent via the PRINTOUT menu bar to plot hard copy maps.

5. PRINTOUT

The PRINTOUT option provides access to commands to either produce high quality plot of vector or raster maps in the desired graphic plotter or laser printer.

6. HELP

The HELP menu has been developed to display 'help screen' which consists of informative materials and other descriptive texts directed to be guidances for operators using the MULAR system.

In the research, land valuations, cost estimation and lists of new parcels can be produced by means of the relational database management systems (RDBMS) package (eg ORACLE) where the package not only provides a convenient user interface to create, compute mathematical functions, and maintain multiple user requirements, but also links to a graphic LIS/GIS package (eg ARC/INFO), if needed.

In summary, the proposed schedule for urban land readjustment in Bangkok, Thailand includes data collection, data capture, data analysis by using the MULAR, and output of various graphic and non-graphic data. The surveying and photogrammetry approaches have been performed to yield accurate graphic data while the RDBMS provide a consistent and integrity of non-graphic data. With the help of GIS packages, graphic data, non-graphic data, and programming languages play an important role to meet the requirement of city planners who would like to cope with the urban land readjustment in an effective way.

Chapter 4

ACQUISITION OF DATA FOR URBAN LAND READJUSTMENT IN BANGKOK, THAILAND

4.1 INTRODUCTION

In chapter 4, the acquisition of data for a proposed new style of urban land readjustment in Bangkok is examined. The chapter is presented in six main parts. The first part outlines types of graphic and non-graphic data needed for the schedule. The second part describes two study areas which are situated in the Klong Toei district and the Lad Krabang district, Bangkok, Thailand. The third part explores the applications of surveying and photogrammetric techniques for the proposed schedule. The fourth part shows field survey results while the fifth part deals with the results of the photogrammetric techniques. The final part reviews the utilisation of a digitiser as a data capture device for LIS/GIS.

4.2 TYPES OF DATA NEEDED FOR THE PROPOSED SCHEDULE

The demand for geographic data has not been confined to earth scientists. City planners and cadastral/land surveyors need detailed information about the distribution of land and resources in towns and cities while civil engineers need to plan the routes of roads and to estimate construction costs. The tremendous public utility networks (eg electricity, telephone, water supply) also need to be manipulated and recorded. The geographic data have traditionally been presented in the form of a map. Before computers were available, geographic data were presented in a graphical format as points, lines, and areas/polygons which can be drawn on a piece of paper or

film. The data were encoded using symbols, textures, and colours that were explained in the map legend or accompanying text. The map and its documentation constituted the LIS/GIS database. The database is commonly characterised as having two fundamental components: graphic data and non-graphic data (or so-called 'attribute data'). With the advent of computers, both the conceptual methods for spatial analysis and the actual possibilities for quantitative digital thematic mapping and spatial analysis have been able to blossom.

4.2.1 Graphic data

To design and test the MULAR, data were derived from a number of government bodies. In particular, the BMA is a central source of digital cadastral map and non-graphic data for the urban land readjustment procedure. In addition, the DTCP is also a prime source of the Bangkok Metropolis General Plan for undertaking the master concept plan process. The graphic data relevant for executing the MULAR consist of large-scale aerial photographs in paper print type form, coordinates of the ground control points, and all sorts of thematic maps (eg soil map, geologic map), as the details show in Table 4.1.

Data have been collected from several government sectors for the execution of this research. The data are required to facilitate the planning and design of the proposed model for urban land readjustment. The design of such models always involves the use of a wide range of data. Some of these data are collected and utilised in the layout of the proposed road networks: others are identified and performed in the land use analysis. It should be noted that the digital maps (eg building map, and vegetation cover map) in the Klong Toei project and the digital maps (eg cadastral map, building map, vegetation cover map, and digital terrain model) in the Lad Krabang project have been produced recently by means of the AP190 analytical stereoplotter at the Department of Geography, University of Edinburgh, as depicted in Table 4.2.

Table 4.1 Types and sources of graphic data in Bangkok.

Type of data	Scale (1:)	Source	Purpose
First-class ground control coordinates (XYZ)	-	RTSD	Control survey for GPS mensuration
Topographic map	50000	RTSD	Site survey planning
Adjusted minor control points (XY)	-	DOL	Preparation of digital maps
Cadastral map	1000	DOL	Layout of the proposed road network
Aerial photographs (panchromatic, paper print)	6200	RTSD	Digital mapping
Cadastral map	2000	BMA	Design of land valuation
City map	4000	BMA	Design of urban land readjustment
General purpose map	10000	BMA	Field work preparation
Geologic map	250000	DMR	Design of urban land readjustment
Soil map	100000	DLD	Design of urban land readjustment
Bangkok Metropolis General Plan	75000	DTCP	Design of master concept plan

Table 4.2 Types of data produced at University of Edinburgh.

Type of data	Scale (1:)	Purpose
Building map	2000	Evaluation of building in replotting design
Cadastral map	2000	Design of land valuation
Vegetation cover map	2000	Compensation cost for replotting design
Urban facility map	4000	Design of urban facility network
Digital terrain model	-	Evaluation of landfill in replotting design

4.2.2 Non-graphic data

Non-graphic data, which are described as characteristic of features, have been collected from many government agencies for the undertaking of this thesis. Most data have been obtained through the 'interview schedule' - for example, the latest market land price - with village headmen in the Lad Krabang project. Details of the non-graphic data are presented in Table 4.3. These data will play a significant role in the procedure of urban land readjustment, especially in the process of replotting design and cost estimation. The data will be input to the RDBMS where updating and retrieving can be efficiently performed and can easily be linked to graphic data which are stored in the GIS packages.

Table 4.3 Types and sources of non-graphic data in Bangkok.

Type of data	Source	Purpose
Name of landowner	DOL	Query of database in preparation of scheme
Land value	DOL	Computation of land value before and after the project
Percentage of building's depreciation	MOI	Computation of compensation cost
Building cost per square area	MOI	Evaluation of building in cost estimation process
Price of vegetation	MAC	Computation of compensation cost
Electrical installation cost	MEA	Computation of cost estimation
Telephone installation cost	TOT	Computation of cost estimation
Water supply installation cost	MWA	Computation of cost estimation
Road surface cost	NHA	Computation of cost estimation
Drainage system cost	NHA	Computation of cost estimation
Cost of landfill	NHA	Computation of cost estimation
Cost of ground survey	NHA	Computation of cost estimation
Cost of land title	NHA	Computation of cost estimation
Cost of administration	NHA	Computation of cost estimation
Interest during construction	NHA	Computation of cost estimation
Contingencies	NHA	Computation of cost estimation
Population data	NSO	Projection of future population

4.3 SITE SELECTION AND BOUNDARY

In the thesis, an attempt is made to apply different approaches of the LIS/GIS techniques to two different areas. Two study areas, urban and suburban areas of Bangkok Metropolis, have been chosen for the reason that urban and suburban land readjustment approaches are both critically important to land acquisition and land management in Thailand. The study areas are shown in Figure 4.1. For an urban area, the LIS/GIS technique will be utilised as a powerful mechanism for city planners to cope with the rearrangement of land use. In a suburban area, the LIS/GIS will be performed as a tool to manage the public utility networks related to all land parcels. Existing city maps, sponsored by the JICA, and rectified large-scale aerial photographs of scale 1:1,000, produced by the DOL, are important appliances to identify and designate the boundary of the sites.

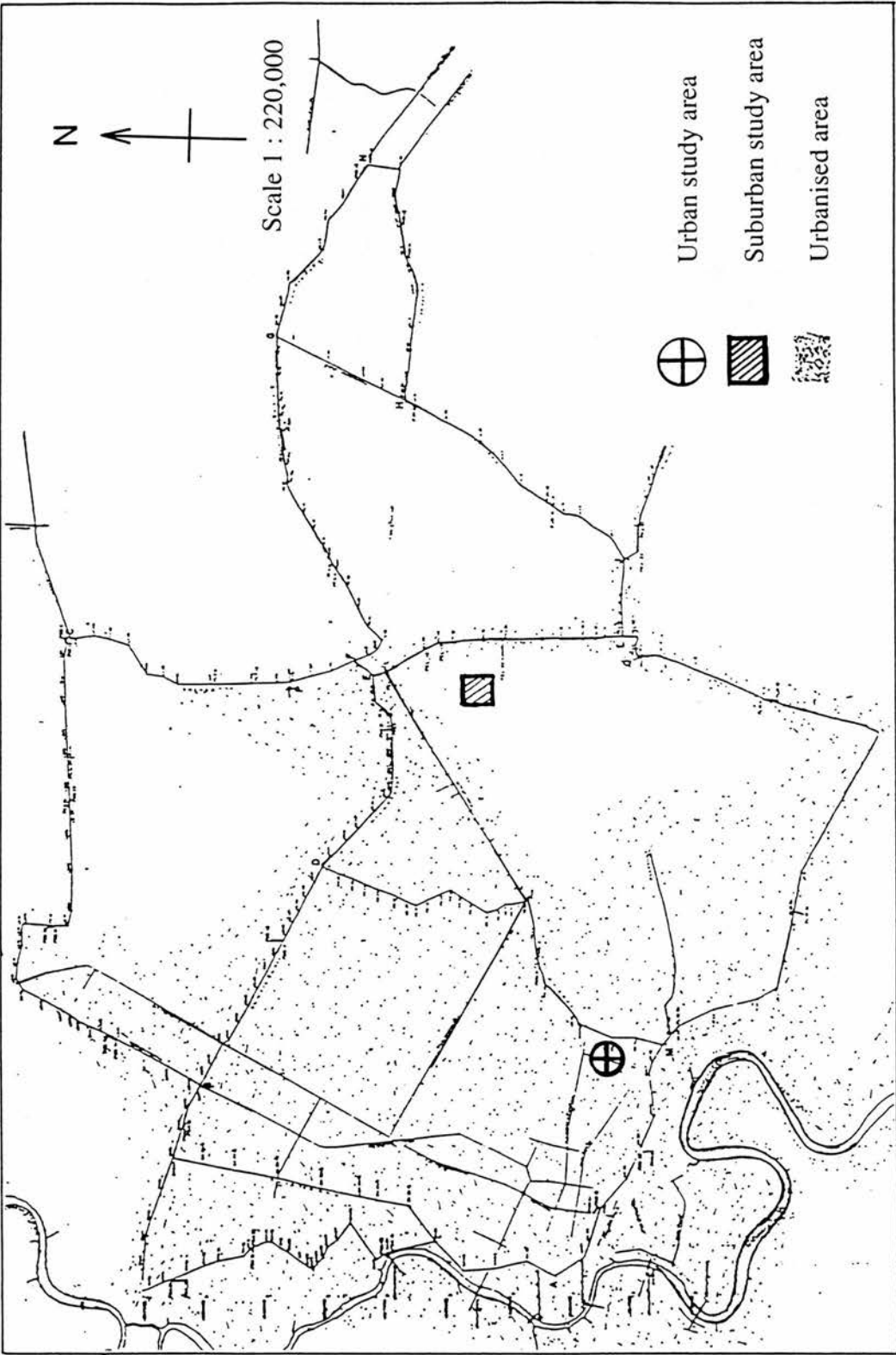


Figure 4.1 The study areas in Bangkok Metropolis, Thailand.

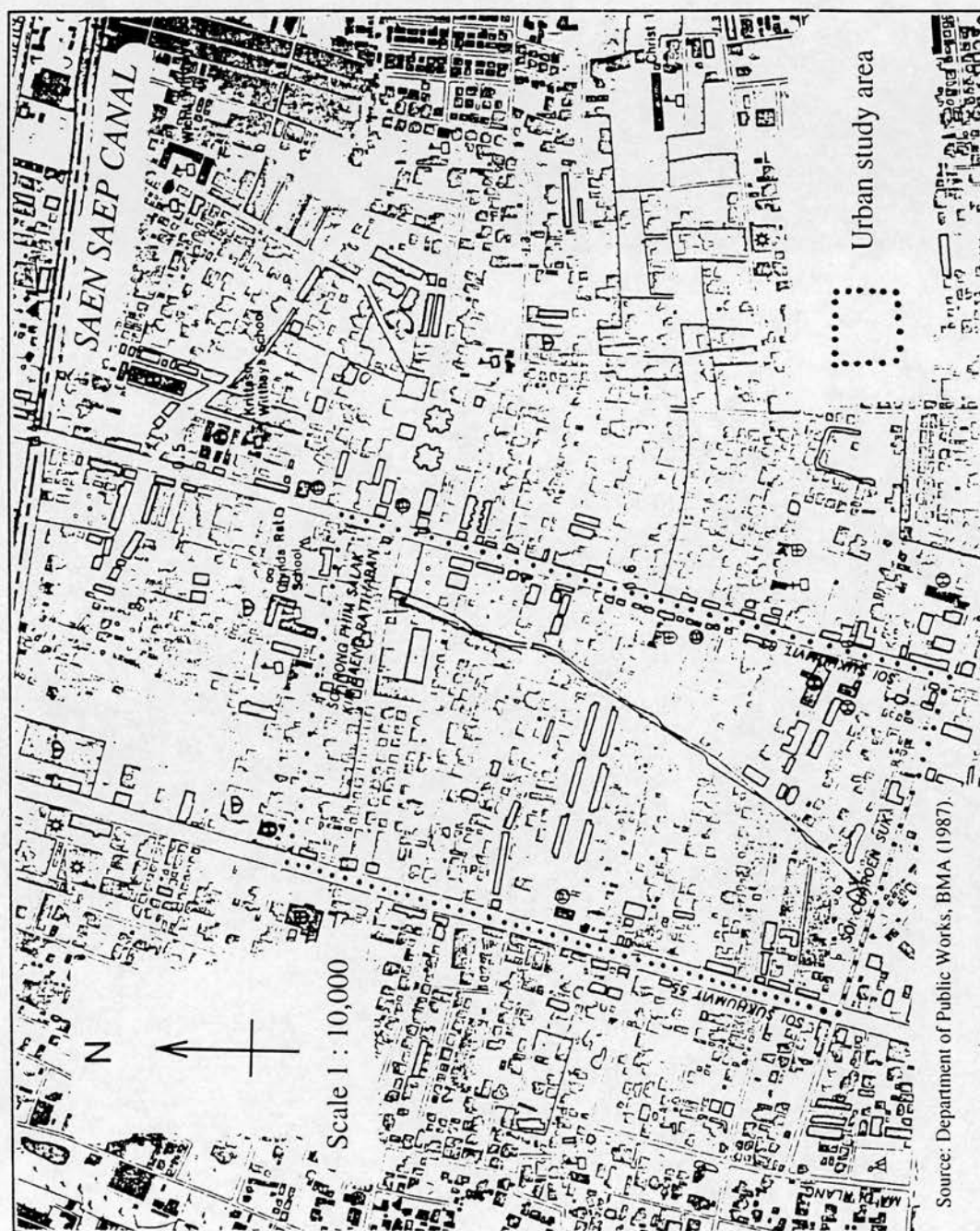


Figure 4.2 The study area in the Klong Toei district, Bangkok.

(1) Urbanised area in the Klong Toei district

The first site selected for the study is located in the Klong Toei district. The size of the area is approximately 0.5 square kilometres, of approximately rectangular shape, with a total number of about 650 housing units in the plan. The area is bounded by Chaem Chan Lane to the North, Sukhumvit 63 Lane to the East, Charoen Suk Lane to the South, and Sukhumvit 55 Lane to the West (Figure 4.2). Public transportation networks - buses and mini-buses - are available on the Sukhumvit 63 Lane; in addition, good urban utility networks such as electricity, private telephone, and water supply are distributed throughout the plan area. There is a small canal, Klong Paeng, within the middle of the study area. Existing land parcels in this area are typically long and thin, sometimes as narrow as 20 metres, and 240 metres long. As the area is being developed with a number of road networks, the canal is not now being used. Moreover, the area was designated by the DTCP in the Greater Bangkok Plan 1992 as a medium density residential area with numerous land use activities such as residential, commercial, and other institutional areas. For this flat, urbanised area the thesis will mainly focus on the application of urban land readjustment for 'rearrangement of land use'.

(2) Suburban area in the Lad Krabang district

The second site selected is situated in the Lad Krabang district; the site covers an area of one square kilometre. The area is now deserted rice field which lies on the western side of the NHA Community Housing Project to the East, the NHA owned land for Police Officials Housing Project to the South, private lands and a public waterway to the West (Figure 4.3). The typical existing land parcel in this area is long and thin, sometimes as narrow as 30 metres, and 600 metres long. Accessibility is usually only by canals running perpendicular to the parcels, so that each parcel fronts onto the canal.



Figure 4.3 The study area in the Lad Krabang district, Bangkok.

The infrastructure networks are simply a distributor, Ratpatthana Road which lies in the middle of the plan area on the east-west direction with right of way of 20 metres, and an electricity network installed along the southern part of the Lum Nai So. Public transportation is not available in the area. Also, the area has no water supply system; the residents therefore have to depend on surface water; canals, and the deep well. The study area at present consists of 2 villages with 27 land parcels. The first is so-called 'Mu Si'; it occupies the northern part of the plan area with 9 land parcels. The second is 'Mu Sam'; it was noted that there were 7 houses in Mu Si and 6 houses in Mu Sam.

The second study area is exactly the same area used in the experimental land readjustment project conducted by the NHA in the late 1992 as mentioned in chapter 2, section 2.9.2. Therefore, the area is being reviewed in another scenario which will be directed to the application of LIS/GIS for land readjustment for opening up the 'pocket land'.

4.4 THE APPLICATIONS OF SURVEYING AND PHOTOGRAMMETRIC TECHNIQUES FOR THE PROPOSED SCHEDULE

The existing urban and suburban cadastral maps in developing countries are often out of date, cluttered in detail, incomplete, or at too small a scale. The problem is particularly critical in Bangkok, Thailand, where the rapid urban growth rate means that existing maps are soon in need of revision. Such maps are deemed to play a significant part for city planners whenever urban land readjustment is taking place. The current methods based on ground survey are slow and labour intensive. Consequently, an alternative scheme involving up to date large scale aerial photographs, GPS and an analytical stereoplottter has been developed, which it is hoped can better fulfil the need of city planners (Chanlikit, 1995). The application of these techniques is presented in successive steps. These steps are field work

preparation, reconnaissance and field classification, mensuration by GPS, aerial triangulation, provisional digital mapping, field completion and classification of land use, building type, and vegetation cover type.

4.4.1 Field work preparation

Preparatory work included the use of aerial photographs and maps for determining GPS and other ground control points. Adkins and Lyon (1991) point out that aerial photographs can be valuable in planning a GPS survey because the photographs make it possible to identify unsuitable locations quickly and without much effort. The photogrammetrist has every justification for keeping the amount of ground control to a minimum, as fieldwork is considerably more expensive than office work because of the attendant costs of accommodation, transport, travelling time and waiting around for the weather to improve (Leatherdale, 1988). In the Lad Krabang project, aerial photographs of scale 1:6,200 and general purpose maps of scale 1:10,000 were used to find the most feasible sites for the location of five GPS stations (DC11, DC12, DC13, DC14, and DC15). Each GPS station was checked stereoscopically using a mirror stereoscope and parallax differences were observed using a parallax bar for computation of the height of high trees, and buildings that could obstruct a clear view of the sky. Normally the orbital path of the GPS satellites will be close to circular with a semimajor axis of about 26,000 kilometres above the Earth's surface. Because of their high altitude, the GPS satellites can be viewed simultaneously from a large portion of the Earth. The satellites are observed only once they are above a certain vertical angle, referred to as the 'mask angle'. The reason for using a mask angle is that tropospheric effects on the signal propagation are especially unpredictable for altitudes within the mask region.

At the designated location of station DC13, it was found that a three-storey concrete building impeded the view of the sky - both in vertical (γ) and horizontal angle (α) of object as shown in Figure 4.4 - at vertical and horizontal angles of about 22 and 28

degrees respectively. At the location of station DC14, it was found that a five-storey concrete building obstructed the view of the sky at vertical and horizontal angles of about 27 and 71 degrees respectively. The vertical and horizontal angles of the two buildings were computed by writing a PASCAL program which is described in Appendix 4.1. However, as the height and length of the buildings are relatively not high or long distance, therefore, all the three GPS receivers have been set at a mask angle (θ) of 15 degrees.

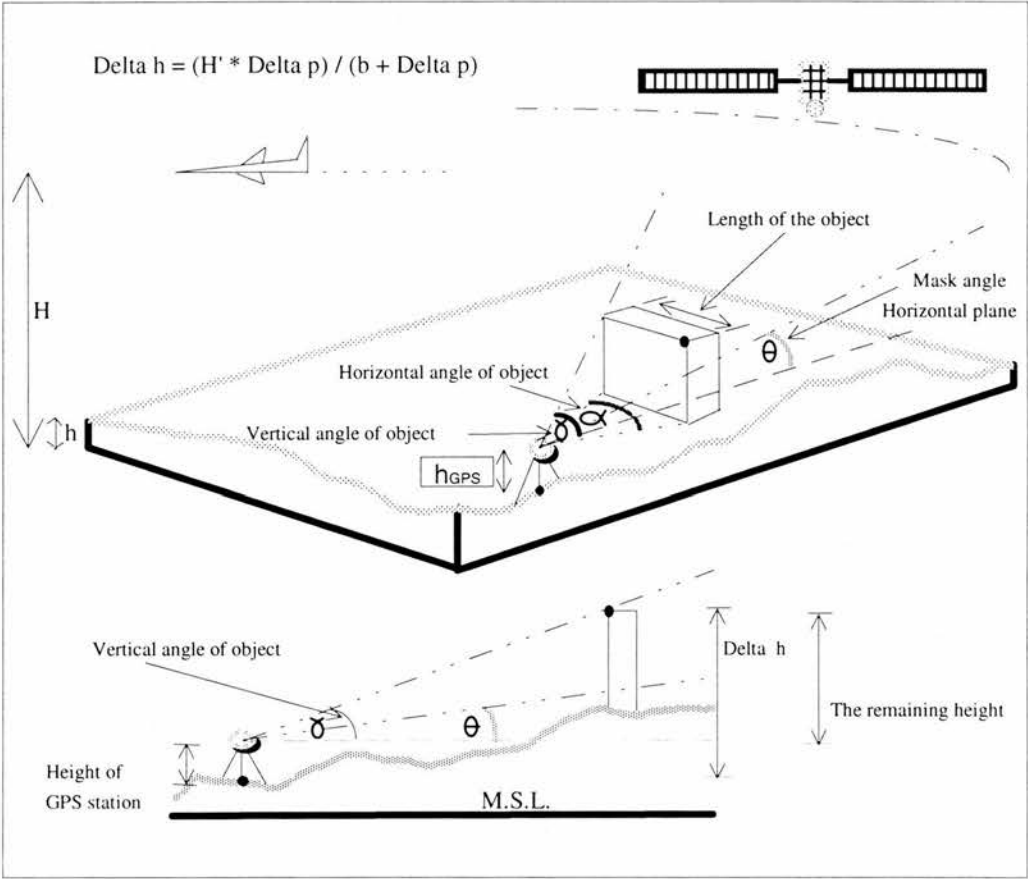


Figure 4.4 The computation of mask angle for setting of GPS receiver.

A city map at a scale of 1:4,000 (Series 9013 S-04, sheet 11-3-D) is available only in the densely urbanised area while general purpose maps at a scale 1:10,000 cover the whole of Bangkok Metropolis area. The maps have been introduced to aid in the field work preparation, for example, in photo indexing, allocation of ground control points

for a GPS, and designation of vertical and horizontal points for aerial triangulation. The geological map of scale 1:250,000 and a soil map of scale 1:50,000 cover both of the project areas and have been taken into account as significant data for urban land readjustment. In addition, an uncontrolled mosaic of aerial photographs in the Lad Krabang district was utilised for planning of ground control and minor control points in the aerial triangulation process.

For horizontal control points, the Royal Thai Survey Department (RTSD) provided a first order horizontal control point (RS29) which is based on the Universal Transverse Mercator (UTM) projection, derived from geographical coordinates based on the Indian Datum as readjusted in 1975. The control point is located in a temple, Wat Rajkosa, which is about 15 kilometres Southeast of the Lad Krabang project. The point was transformed to the World Geodetic System 1984 (WGS84) and was then used in TRIMVEC software as a reference location for coordinate adjustment.

For vertical control points, the first class levelling survey routes adjacent to the study area in the Lad Krabang district has been established in the project undertaken by the RTSD since 1978 (BMA, 1987). For the research, the RTSD provided two of the first order levelling points, BMS 9205-2/32 and BMP 470. The first is about 3 kilometres Northeast and the second is about 15 kilometres Southeast of the Lad Krabang project.

4.4.2 Reconnaissance and field classification

A general examination or survey of the main features, or certain specific features, of a region is required, usually as a preliminary to more detailed survey. A reconnaissance survey is usually executed rapidly and at relatively low cost. The information obtained is recorded, to some extent, in the form of a reconnaissance map or sketch. In addition, field inspection and identification of features which a map compiler is unable to delineate, identification and delineation of administrative

boundary lines, place names and road classifications may also be included as part of the control survey effort and normally are completed prior to the actual stereocompilation phase. In many circumstances, field classification should be carried out by the photogrammetrists who are in charge of the subsequent stereocompilation in order to acquaint them with the project area.

A reconnaissance and field classification in the Klong Toei project revealed that there was heavy vehicular traffic and great difficulty was experienced in finding suitable sites at ground level for survey control markers that were safe from interference. Moreover, high-rise buildings are a hindrance to GPS observations. As a result, it was decided to make use of reliable horizontal coordinates from the DOL which were adjusted in UTM system by means of an independent model block adjustment program (PAT-M43) carried out in 1989.

A reconnaissance was also undertaken in the Lad Krabang project. Four full ground control points were located in the perimeter and a fifth point was located approximately in the middle of the survey area. In addition, eleven vertical control points were designated along the survey routes. The reason for the number and distribution of control points was in order to enhance a rigorous independent model block adjustment.

4.4.3 Mensuration by GPS

Since the Gulf War, the Global Positioning System (GPS) surveying has certainly found its place in the public awareness. GPS receivers were used on ships, tanks, helicopters and by troops to rapidly provide position information (Leick, 1992). It is anticipated that GPS will soon provide 24-hour all weather navigation anywhere on Earth. One major advantage of GPS surveying has over conventional angle and distance work is that line-of-sight restrictions are not enforced (Gerdan, 1992). Leick (1990) pointed out that GPS surveying to 1-2 ppm is routinely carried out by many

individuals and companies around the world. With several days data, and special techniques, accuracy of about 0.01 metres can be maintained up to about 1,000 kilometres (Cross, 1991). Both GPS and LIS/GIS are also changing so rapidly that there will be many applications in the near future that have never been thought of today. LIS/GIS users have always had to encounter the problem of providing a spatial reference of their data and GPS is just another solution to provide this. The Trimble 4000ST GPS Surveyor (Plate 4.1) is designed for high-precision survey applications. When used with Trimvec PlusTM suite of software, three-dimensional coordinate differences between stations can be determined. The 4000ST receives L1 signal (1574.42 MHz) sent from the Global Positioning System NAVSTAR (Navigation Satellite Timing and Ranging) satellites. In the Lad Krabang project three identical Trimble 4000ST GPS Surveyor receivers were used to undertake static and differential surveys.



Plate 4.1 The Trimble 4000ST GPS receiver set at point RS29, Wat Rajkosa, Bangkok, Thailand.

Of the four different methods of using the GPS equipment (Trimble Navigation, Ltd., 1991), the pre-planned survey method together with ‘once at specified date and time’ mode was chosen because this method has the advantage of being pre-programmed into the 4000ST, either from a computer or the 4000ST front panel, prior to running the survey. Consequently, the basic steps required to schedule a survey into the 4000ST were session, station-ID, and survey start and stop time as shown in Table 4.4. For instance, the three identical Trimble 4000ST receivers (GPS I, GPS II, GPS III) were set over designated points DC11, DC12 and DC13 successively by the day-of-the-year or Julian day, a digit indicating the run sequence (318-1, 318-2, and so forth) at 0800 - 1000 a.m.

Table 4.4 Pre-planned survey by means of the Trimble 4000ST GPS receivers.

Session	Station-ID and GPS receiver			Time
318-1	DC11 / GPS I	DC12 / GPS II	DC13 / GPS III	0800 - 1000
318-2	DC11 / GPS I	DC14 / GPS II	DC13 / GPS III	1030 - 1230
318-3	DC12 / GPS I	DC14 / GPS II	DC15 / GPS III	1300 - 1500
318-4	DC12 / GPS I	DC14 / GPS II	RS29 / GPS III	1600 - 1800

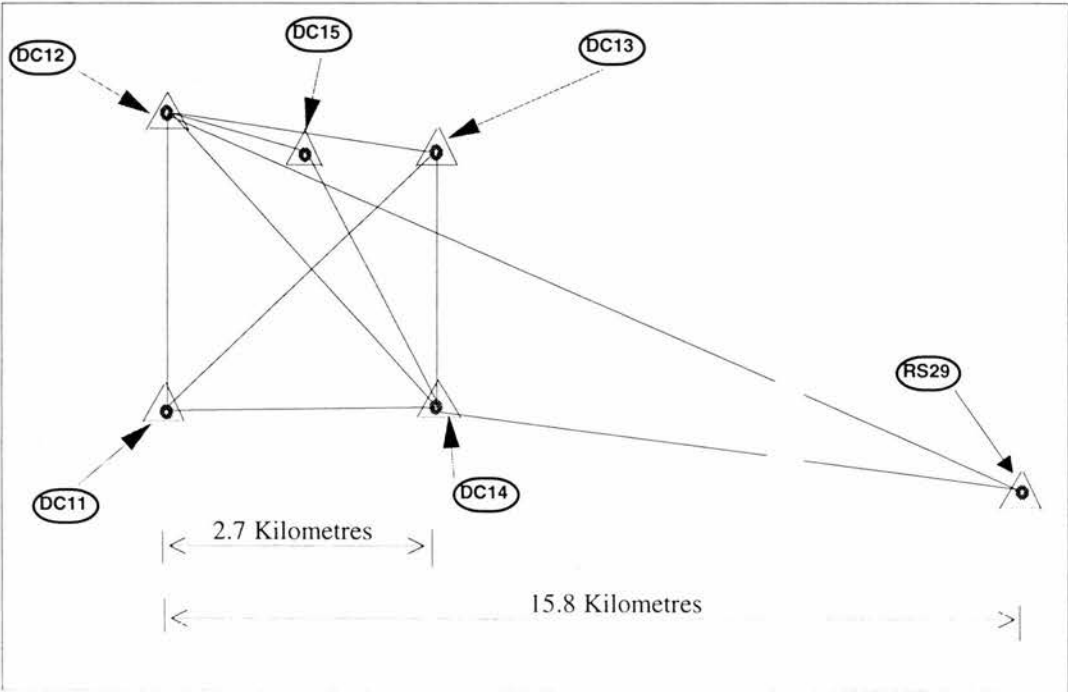


Figure 4.5 GPS network in the Lad Krabang project.

Figure 4.5 shows the relationship between the six GPS stations. The rationale of the field operation involved three trained assistants, three labouring assistants, two cars and three walkie-talkie receivers. The known coordinate point (RS29), which was transformed to WGS84, was introduced into the microcomputer during processing to compute accurate coordinates of the five unknown points (DC11, DC12, DC13, DC14, and DC15).

4.4.4 Heighting

A vertical control survey for photogrammetric purposes was required for all the designed points in the Lad Krabang project. All elevations were referred to Bench Mark 9205-2/32 (elev. 1.0524 m, 1989). In addition, an elevation of the first order horizontal control point (RS29) was also referred to Bench Mark 470 (elev. 1.6760 m, 1989). Both of these are located in Wat Rajkosa, Lad Krabang district, Bangkok Metropolis. The vertical survey was completely by levelling, using a WILD NK2 level.

4.4.5 Aerial triangulation with independent model block adjustment

Aerial triangulation (or so-called ‘aerotriangulation’) can be defined as a procedure for the determination of horizontal or vertical control coordinates (minor control points) from measurements of angle, distance, or coordinates of points on overlapping photographs. Johnson *et al.* (1980) described aerial triangulation as ‘the process for the extension of horizontal and/or vertical control whereby the measurements of angles and/or distances on overlapping photographs are related into a spatial solution using the perspective principles of the photographs’.

In this research, an independent model block adjustment is applied. The advantage of the block adjustment is that measurements of coordinates of points, on a large number of photographs, are converted to the corresponding coordinates of the ground

points, for all the points at one time, rather than individually for selected subsets of the points. In other words, the exploitation of block adjustment is to determine the absolute orientation of many models simultaneously. The models are linked together using tie points and pass points, and the block is transformed to the ground coordinate system through the ground control points. Beyond that the planimetric iteration step is linear and therefore requires no initial values of scale and azimuth. For that reason, no procedures are necessary for obtaining pre-transformed model coordinates.

Weighting of observations (w) is rather straightforward, because the model coordinates x, y, z are used in two separate adjustments (planimetry and height). In general, the available ground control coordinates are not error free; as a result, the control point coordinates are treated as observations. If a control point is to be kept unchanged, an infinite weight is assigned to its coordinates. In this research, the following weights have been applied for homogeneous data.

- For the ground control points, the weight ($w_x = w_y = w_z$) is designated to be 0.20.
- For model points of planimetric block adjustment, the weight ($w_x = w_y$) is equal to 0.20. The weight (w_z) is also equal to 0.20 in height block adjustment.
- For perspective centres of planimetry and height, the weight ($w_x = w_y = w_z$) is equal to 0.20.

With respect to accuracy of the block adjustment, the planimetry and height iterations are repeated 3 times. Usually, the process is terminated following the second or third height iteration step, after which the final terrain coordinates are computed (Ebner and Fritz, 1980).

In the Lad Krabang project, there were 3 strips of stereomodels; each strip was composed of 5 stereomodels. The independent model block adjustment was carried out using the BLOKK program, version 7.0, which was developed by Carto Instruments, Norway. Like other well-known programs, the BLOKK program also provides choices, namely, adjustment of planimetry, adjustment of height, adjustment

of three dimension (or planimetry and height). Above all, the program runs on a microcomputer (IBM AT or compatible) and the input is data collected with the AP190 analytical stereoplotter which is already available in the Department of Geography, University of Edinburgh (Plate 4.2).



Plate 4.2 The AP190 analytical stereoplotter, Department of Geography, University of Edinburgh, U.K.

A number of independent model blocks were observed by using four different sets of ground control point files - as shown in Appendix 4.2, Appendix 4.3, Appendix 4.4, Appendix 4.5 - for the reason that the best result would be used as a ground control point file in the absolute orientation process for digital mapping procedures. The four sets of ground control point files were as follows:

- SET 1: A block of 5 full ground control points (XYZ);
- SET 2: A block of 5 full ground control points (XYZ) and 11 vertical ground control points (Z);

- SET 3: A block of 5 full ground control points (XYZ) and 12 additional vertical control points (Z);
- SET 4: A block of 5 full ground control points (XYZ), 11 vertical ground control points (Z) and 12 additional vertical control points (Z).

Panchromatic aerial photographs (paper print type) at a scale of 1:6,200, taken with normal-angle lens metric camera, were employed for the independent model block program. The independent model block of 15 models was observed in the AP190; with SET 1 the models were linked by using 24 tie points and 33 pass point, as shown in Figure 4.6. The block was transformed to the ground coordinate system through the 5 full ground control points (XYZ) by means of the BLOKK program.

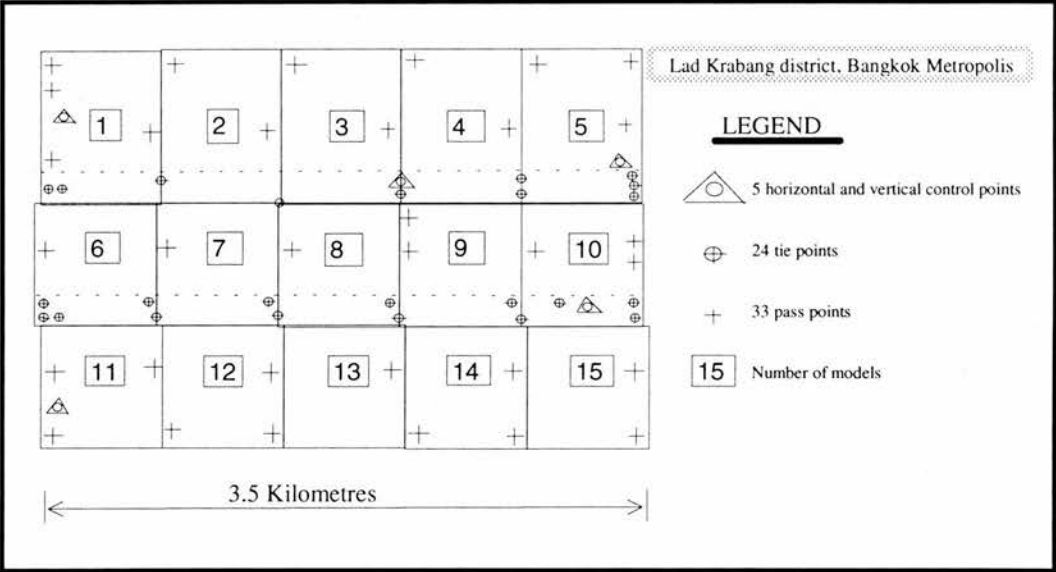


Figure 4.6 The independent model block adjustment with 5 full ground control points (SET 1).

With SET 2 the independent model block of 15 models was observed and linked by using 17 tie points and 29 pass points (Figure 4.7). The block was transformed to ground coordinate system through 5 full ground control point (XYZ) and 11 vertical ground control points (Z) by means of the BLOKK program.

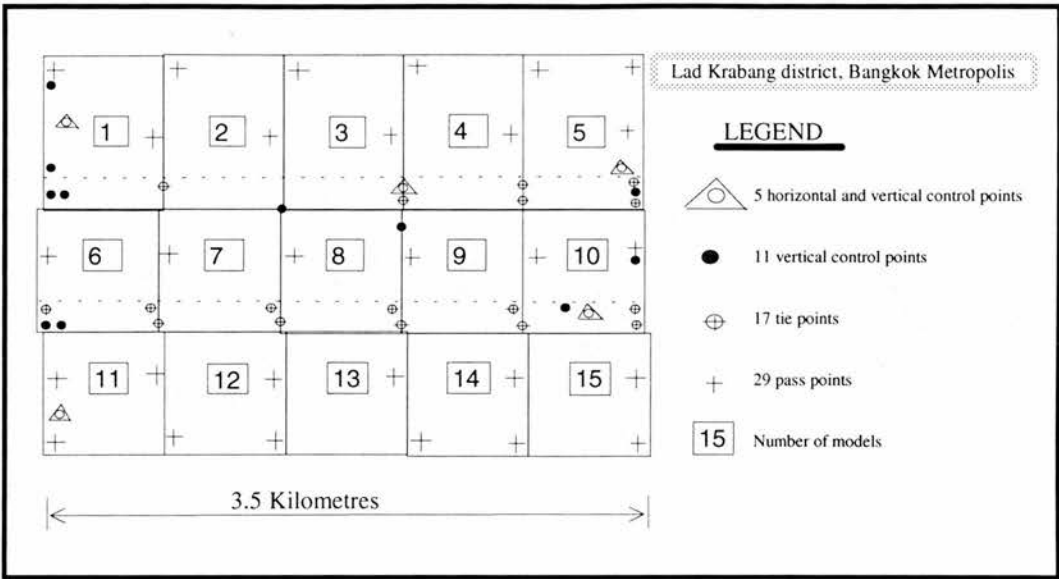


Figure 4.7 The independent model block adjustment with 5 full ground control points and 11 vertical ground control points (SET 2).

The existing general purpose map of scale 1:10,000 (Series 9013 S-1, sheet 12-1 and 12-3) were utilised as data sources for acquisition of 12 additional vertical control points. The additional points are already located on the maps as spot height data which correspond to 12 well-defined points in aerial photographs. With SET 3 the block was observed and linked together using 24 tie points and 21 pass points (Figure 4.8). The block was later transformed to the ground coordinate system through 5 full ground control points (XYZ) and 12 additional vertical control points (Z) by using the BLOKK program.

With SET 4 the block was observed and linked together using 17 tie points and 17 pass points (Figure 4.9). The ground coordinates were determined through 5 full ground control points (XYZ), 11 vertical ground control points (Z), and 12 additional vertical control points (Z) by using the BLOKK program.

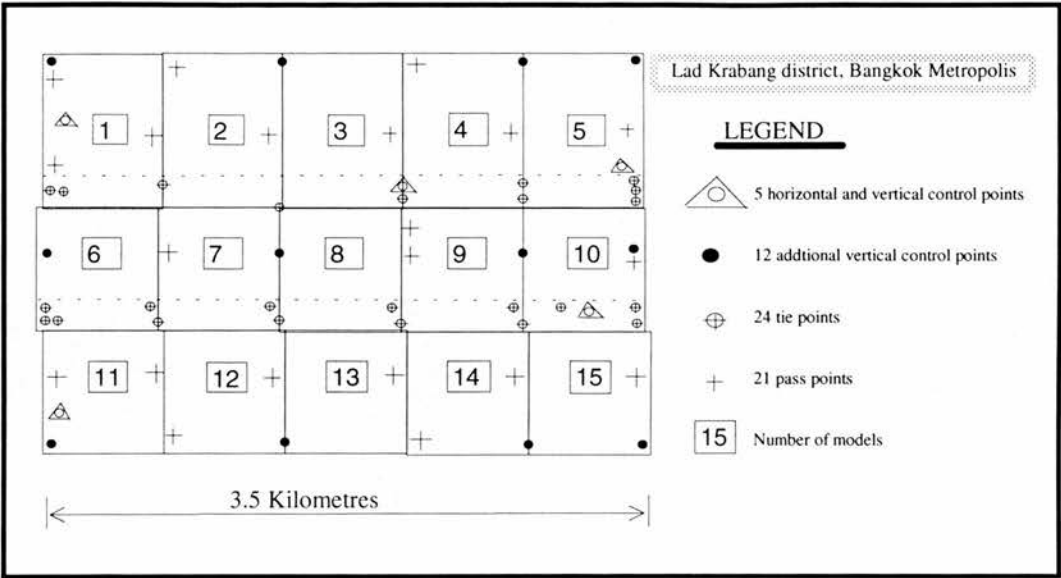


Figure 4.8 The independent model block adjustment with 5 full ground control points and 12 additional vertical control points (SET 3).

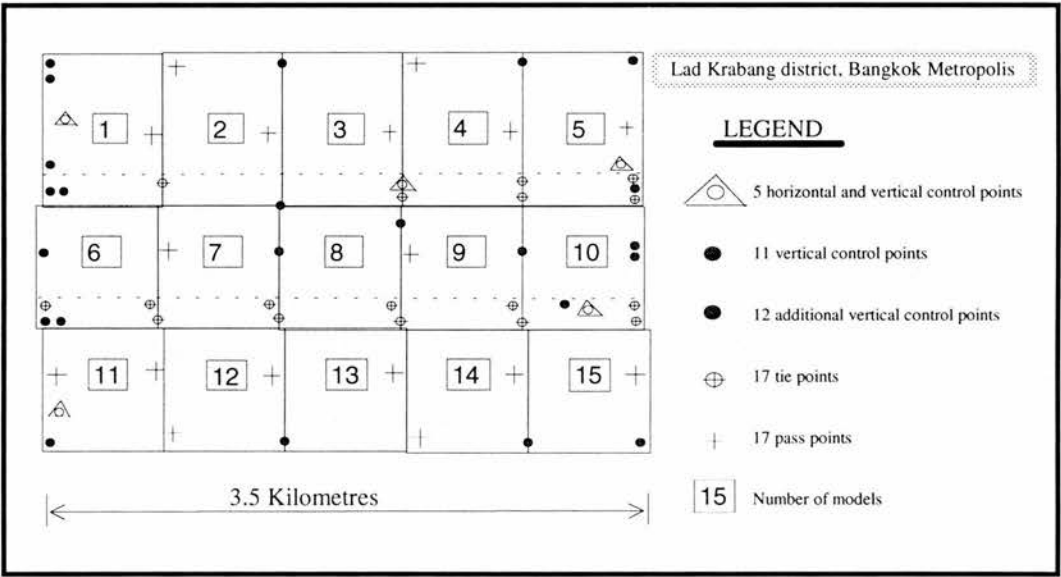


Figure 4.9 The independent model block adjustment with 5 full ground control points, 11 vertical ground control points, and 12 additional vertical control points (SET 4).

4.4.6 Provisional digital mapping

In the Klong Toei project, a provisional digital cadastral map and a building map were provided by the BMA, both at 1:4,000 scale. It was obvious that there were

some mistakes in the provisional building map, for example, irregular shapes of the buildings. Therefore, it was decided that the provisional digital building map would have to be replotted. This would be done at the Department of Geography, University of Edinburgh, using four rigorous horizontal control points provided by the DOL (Thailand), an AP190 analytical stereodigitiser and the ARC/INFO utilities.

In the Lad Krabang project, a provisional digital cadastral map and a building map were produced by means of adjusted minor control points. The points derived by using an independent model block adjustment program, PAT-M43, which was installed at the DOL, Thailand. The provisional maps were produced by using panchromatic aerial photographs (paper print type) in an analytical stereoplotter Wild BC1 in the Department of Survey Engineering, Chulalongkorn University, Bangkok, Thailand. Viewing in three dimensions was rather poor since the stereoplotter was designed to cope normally with diapositives. The provisional cadastral map represented 28 parcels of land and the provisional building map consisted of 13 houses (in 1988) at a scale of 1:4,000.

4.4.7 Field completion

Inspections or surveys made in the field are required to complete, check, or correct photogrammetrically prepared portions of a map manuscript. A field completion may be done either before or after photogrammetric completion. Among the items checked or added are place names, administrative boundaries, elevations, distances, types of roads, and nature of vegetation. In many cases, it is more preferable to carry out field completion after the compilation.

In the Klong Toei project, the digital cadastral and building maps (sponsored by the BMA) and the aerial photographs at a scale of 1:6,200 were used extensively for field completion. The DOL is normally responsible for the cadastral map (hard copy type). Therefore, it had to be assumed that the cadastral map was up to date and did not

require revision since there was no more up to date land evidence from the DOL. Features on the current public utility maps (eg location of electrical pole, telephone booth) have been located by means of offset with tape and optical square.

In the Lad Krabang project, the provisional cadastral map and building map of scale 1:4,000, aerial photographs at a scale 1:6,200, and large-scale cadastral map (sponsored by the DOL) of scale 1:1,000 were used for field completion. As before the location of current electrical poles have been found by offset with tape and optical square.

4.4.8 Classification of land use, building type, and vegetation cover type

There can be no doubt of the significance of land use because the use of any given parcel of land affects not only those who reside there or have use of that land - for whatever purpose - but also those who live on or have use of adjacent and surrounding areas (Rhind and Hudson, 1980). In this research, classification of land use, building type, and vegetation cover type has been determined simultaneously with the field completion process for the reason that the classification will play an important role as a guidance in the layout design and replotting design procedure.

The land use classification has been adapted from a standard land use classification of Mapping Division, DTCP, Thailand (eg residential, commercial, institutional), as shown in Appendix 4.6.

Building type has been adapted from a standard of Building Assets Assessment List (1992), Assets Assessment Committee, MOI, Thailand (Appendix 4.7). The list will play a key role in computing of current building cost in urban land readjustment procedure (eg detached house, bungalow, town house).

Vegetation cover type classification has been adapted from a List of compensation cost of tree launched by the Ministry of Agriculture and Co-operatives, Thailand (Appendix 4.8).

4.5 THE RESULTS OF CONTROL SURVEY

In this research, the three identical Trimble 4000ST GPS receivers were used in order to get accurate ground control coordinates (XY) and a Wild NK2 level was exercised for heighting (Z).

4.5.1 Processing GPS survey data

Processing the GPS survey data requires the use of the TRIMVEC PLUS postprocessing software and a computer with 640 KB of RAM and a maths co-processor chip. In the research, a microcomputer with a hard disk was utilised. The process involved downloading the GPS survey data from the three receivers and using the Automatic Processing option, after which the downloading data was computed and adjusted as shown in Table 4.5 and Table 4.6.

Table 4.5 Summary of coordinate adjustment (fixed XYZ at point RS29).

Pt #	Station-ID	Northing (m)	Easting (m)	Height (m)	Known
1	DC11	1521078.826	684797.041	4.47	YXZ
2	DC12	1523542.753	684717.421	1.33	YXZ
3	DC13	1523034.411	687598.601	-0.11	YXZ
4	DC14	1521606.419	687478.701	-0.53	YXZ
5	DC15	1522815.163	686393.955	0.89	YXZ
6	RS29	1515060.804	700606.448	0.58	YXZ

Table 4.6 Summary of coordinate adjustment (fixed XY at point RS29 and fixed Z at point DC11).

Pt #	Station-ID	Northing (m)	Easting (m)	Height (m)	Fixed	Known
1	DC11	1521078.826	684797.041	5.16	--Z	YXZ
2	DC12	1523542.753	684717.421	2.02	-	YXZ
3	DC13	1523034.411	687598.601	0.58	-	YXZ
4	DC14	1521606.419	686478.701	0.15	-	YXZ
5	DC15	1522815.163	686393.955	1.58	-	YXZ
6	RS29	1515060.804	700606.448	1.27	YX-	YXZ

The known coordinates of station RS29 (Indian datum 1975) were required and converted to WGS84 datum for computation of coordinates of the five unknown stations (DC11 - 15). The computed coordinates were then converted to Indian datum 1975 by means of the software. There was no doubt about the precision of the XY coordinates from GPS (horizontal precision), which matched its first-order specification (Table 4.7). An interesting difference in GPS measurements resulted from the 15 kilometres distance between the reference station RS29 and the five stations in the Lad Krabang area (see Figure 4.5). When the coordinates of station RS29 were fixed in XYZ, the results in height of the five unknown stations differed from their heights derived from field levelling by a mean of approx. -70 cm (see Table 4.5). In contrast when station RS29 was fixed in XY only and one of the stations (DC11) was fixed in Z (see Table 4.6), the height errors of the five stations were consistent to a few centimetres with a +70 cm error at RS29. Table 4.8 illustrates the combined effect of the geographical spacing between the reference station and the field area.

Table 4.7 Results of horizontal precision from GPS (using the Automatic Processing option) in the Lad Krabang district, Bangkok.

From	To	Horizontal precision
DC11	DC12	1: 791,948
DC11	DC13	1: 1,270,316
DC11	DC14	1: 941,231
DC11	DC15	1: 510,715
DC11	RS29	1: 12,208
DC12	DC13	1: 905,842
DC12	DC14	1: 1,228,322
DC12	DC15	1: 487,116
DC12	RS29	1: 14,250
DC13	DC14	1: 435,809
DC13	DC15	1: 255,922
DC13	RS29	1: 12,714
DC14	DC15	1: 498,006
DC14	RS29	1: 11,350
DC15	RS29	1: 12,906

Table 4.8 Difference in height between ground control survey and GPS.

Station-ID	Ground control (m)	GPS (m)		Difference (m)	
		Fixed RS29	Fixed DC11	RS29	DC11
DC11	5.16	4.47	5.16	-0.69	0
DC12	2.08	1.33	2.02	-0.75	-0.06
DC13	0.53	-0.11	0.58	-0.64	0.05
DC14	0.11	-0.53	0.15	-0.64	0.04
DC15	1.58	0.89	1.58	-0.69	0
RS29	0.58	0.58	1.27	0	0.69

The explanation for the height errors relates to the figure of the Earth. The ellipsoid used internally in the 4000ST is that developed from the WGS84. The WGS84 ellipsoid is a smooth, mathematically convenient surface which facilitates the representation of latitude, longitude and altitude within the 4000ST receiver. The ellipsoid is only an approximation to the surface of the Earth. At the same time, the geoid is based on the gravity equipotential surface, and the geoid accurately models mean sea level (MSL) around the globe (Magellan Systems Corporation, 1991). Since altitudes on maps are almost always relative to sea level, the altitude presented in Figure 4.10 is the height above MSL, which is the same height above the geoid.

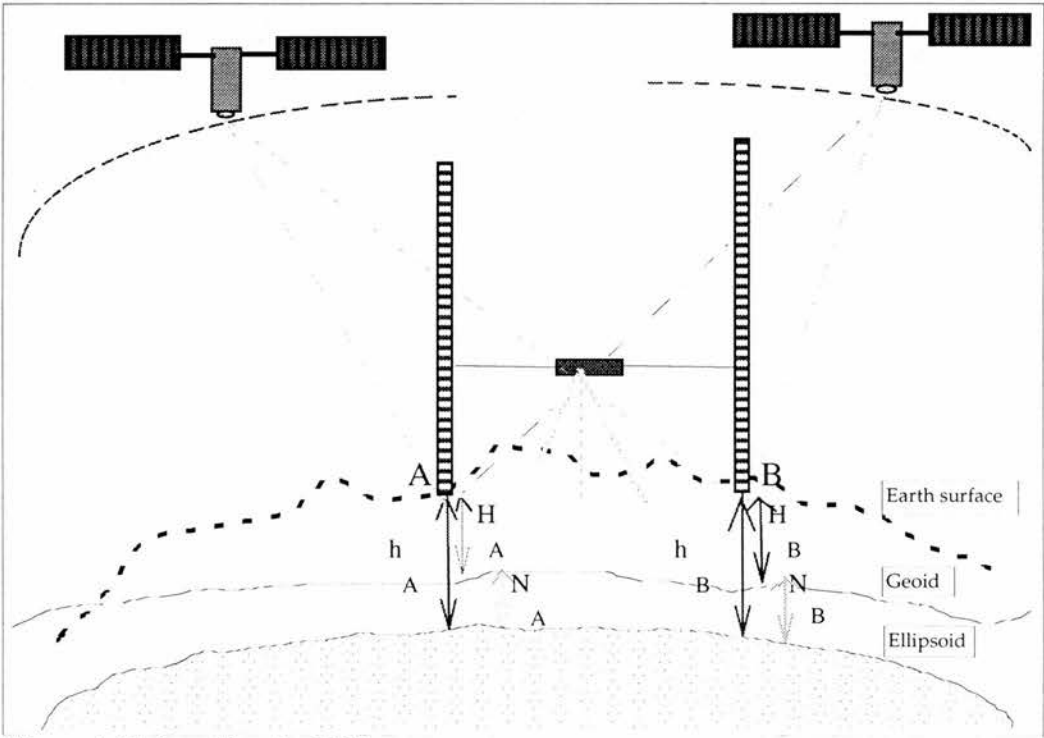


Figure 4.10 Levelling by GPS.

Therefore, after introduction of a mean Earth ellipsoid (WGS84), the coordinate differences Northing and Easting are perfectly well suited to locate the points (DC11, DC12, DC13, DC14, and DC15) on the ellipsoid, but the heights have a severe shortcoming. According to Table 4.8, GPS or geometric height differences (Δh) caused by geoid height differences (ΔN) are approximately 70 centimetres. Consequently, the adjusted height at the points (DC11, DC12, DC13, DC14, and DC15) will be corrected by adding 69 centimetres in height to the point RS29. By this method, the height at point RS29 is now equal to 1.27 m. After re-running the program, the heights of all points were very similar to the heights derived by ground survey.

In this thesis, it is considered that the use of the three identical Trimble 4000ST GPS receivers has greatly improved the ground survey procedures for creating horizontal ground control points (DC11 - 15) for photogrammetry, resulting in higher and more reliable accuracy, and low cost investment in the long run.

4.5.2 Elevation computation

The results of the heighting in the Lad Krabang project were achieved to Thailand’s third order level specifications ($12 K^{1/2}$ mm where K is distance in kilometres) which were accurate enough for observation in GPS and in the process of aerial triangulation (Table 4.9).

Table 4.9 The result of height data (Z) in the Lad Krabang district, Bangkok.

Pt #	Height (m)	Pt #	Height (m)	Pt #	Height (m)
BMP 470	1.676	DC15	1.579	30006	1.084
BMS 9205-2/32	1.052	30001	0.231	30007	0.711
DC11	5.155	30002	0.959	30008	0.898
DC12	2.081	30003	4.319	30009	0.225
DC13	0.531	30004	1.111	30010	1.108
DC14	0.111	30005	0.936	30011	0.309

4.6 THE RESULTS OF PHOTOGRAMMETRIC PROCESSING

On the AP190 analytical stereoplotter, a block aerotriangulation package has been used to densify the minor control points. These points will be used in the process of absolute orientation for producing digital maps in a suburban area, Bangkok.

4.6.1 Assessment of the independent model block adjustment procedure

The AP190 analytical stereoplotter was utilised for collecting unknown digital model coordinates (or so-called ‘minor control points’). The coordinates were later related to four set of known ground control coordinates and they all were computed to get various set of adjusted known coordinate points by means of a BLOKK program which was embedded in the AP190 environment (Figure 4.11).

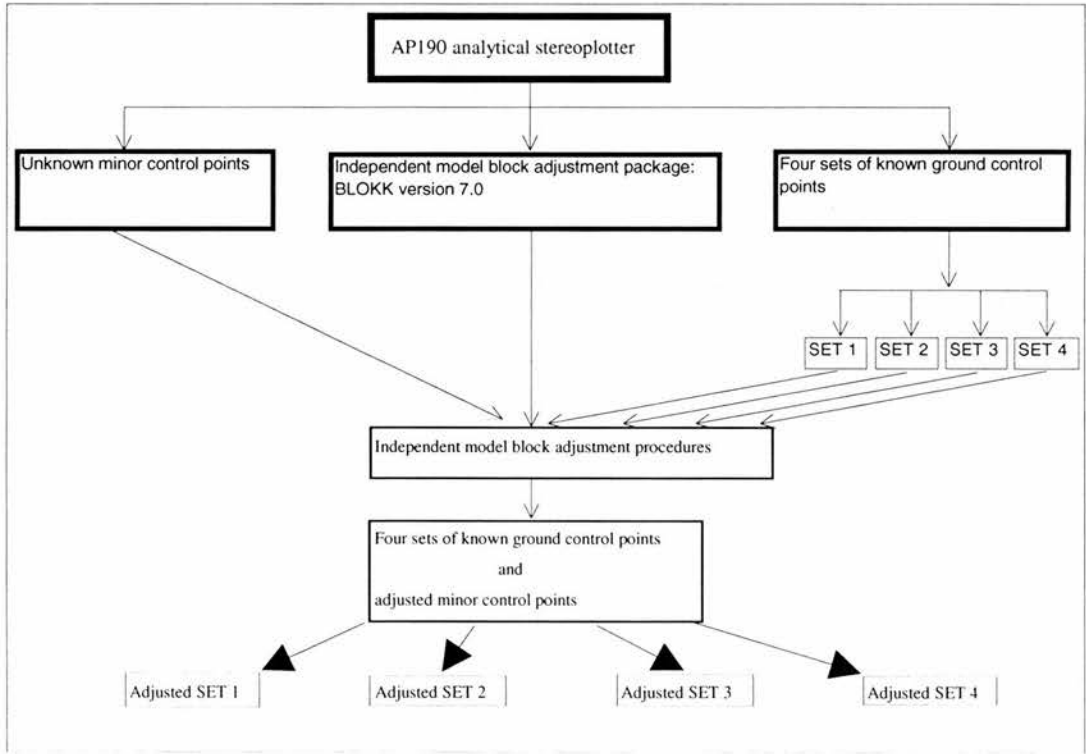


Figure 4.11 Four sets of adjusted minor control points derived by means of independent model block adjustment package (BLOKK) in the AP190 environment.

In SET 1, the input required unknown model coordinates (57 points) of 15 models and the output were the adjusted ground XYZ coordinate values of 24 tie points and 33 pass points, which could be used as control points for absolute orientation of the models. Sigma naught (σ_0) values which represent the standard error of the adjusted coordinates are indicated in Table 4.10.

Table 4.10 The result of independent model block adjustment: SET 1.

Independent model block adjustment	Sigma naught (m unit in terrain)
Planimetry (XY)	0.29
Height (Z)	0.46
Planimetry and height (XYZ)	0.35

Table 4.11 The result of independent model block adjustment: SET 2.

Independent model block adjustment	Sigma naught (m unit in terrain)
Planimetry (XY)	0.29
Height (Z)	0.44
Planimetry and height (XYZ)	0.33

Table 4.12 The result of independent model block adjustment: SET 3.

Independent model block adjustment	Sigma naught (m unit in terrain)
Planimetry (XY)	0.29
Height (Z)	0.47
Planimetry and height (XYZ)	0.35

Table 4.13 The result of independent model block adjustment: SET 4.

Independent model block adjustment	Sigma naught (m unit in terrain)
Planimetry (XY)	0.29
Height (Z)	0.45
Planimetry and height (XYZ)	0.33

In SET 2, the input required unknown model coordinates (46 points) of 15 models and the output were the adjusted ground XYZ coordinate values of 17 tie points and 29 pass points, which could be used as control points for absolute orientation of the models. Sigma naught values are depicted in Table 4.11.

In SET 3, the input required unknown model coordinates (45 points) of 15 models and the output were the adjusted ground XYZ coordinate values of 24 tie points and 21 pass points, which could be used as control points for absolute orientation of the models. Sigma naught values are shown in Table 4.12.

In SET 4, the input required unknown model coordinates (34 points) of 15 models and the output were the adjusted ground XYZ coordinate values of 17 tie points and 17 pass points, which could be used as control points for absolute orientation of the models. Sigma naught values are presented in Table 4.13.

It was obvious that sigma naught values of the block of SET 4 (see Table 4.12) were relatively as good as in the block of SET 2 (Table 4.10). Moreover, the block of SET 4 was composed of 28 control points in total which were considered to be more rigorous than the block in SET 2 which consisted of 16 control points. Therefore, the result of the SET 4 was considered as being most promising as the design for a control point file (Appendix 4.9) for undertaking absolute orientation of stereomodels and was used in order to produce several digital maps.

4.6.2 The transfer of digital data from the AP190 to GIS packages

Nowadays, analytical stereoplotters using sophisticated software are the industry standard. All PC-based analytical stereoplotters (eg Zeiss Planicomp P3, Leica SD2000) are capable of making three-dimensional measurements directly from aerial photographs but they vary in their accuracy and ease of use. The Carto Instruments AP190 analytical stereoplotter permits special functions such as line length, area, height, slope and azimuth (Carto Instruments, 1988) and allows digitisation directly into any CAD or GIS system. Alternatively, the data can be stored in the PC and later easily transferred to an information system for spatial analysis or to a plotter for generating maps (Warner and Carson, 1990). After an absolute orientation is completely created by means of the AP190 analytical stereodigitiser, digital data can

be digitised directly from the stereoscopic models and all binary digital data are converted into ASCII output files which can be divided into two modes: line and point modes.

In this thesis, the use of the AP190 is described for separate research projects in the urban and suburban environment in Bangkok Metropolis, Thailand. For the urban area of Bangkok, the aim was to produce a digital building map and vegetation cover map (eg bamboo, coconut, and mango). In addition, for the suburban area in Bangkok, the AP190 has been used for collecting height data for use in a ARC/TIN program, and for producing several digital maps.

To transfer digital data from the AP190 to ARC/INFO, line mode is one of the options available in graphic commands. A number of ASCII output files in line mode from the AP190 have been transferred to the ARC/INFO via the Geography VAX computer system (GEOVAX), as details shown in Table 4.14.

Table 4.14 The digital data digitised in line mode and transferred to ARC/INFO environment.

Area	Type of digital map	Digitising mode	GIS package
Klong Toei district	Building	Line	ARC/INFO
Lad Krabang district	Building	Line	ARC/INFO
	Cadastral	Line	ARC/INFO
	Land use	Line	ARC/INFO
	Land value	Line	ARC/INFO

In other circumstances, point mode of data transfer is more appropriate. In the Lad Krabang district, a model of digital terrain model (DTM) surface has been constructed from square gridded data of 20 metre distances which are collected in point mode by using the AP190. After digitising, all data which contain X, Y, Z values (as real numbers) are sent to GEOVAX in ASCII format. By means of a FORTRAN program (Appendix 4.10), the Z values are changed to integers which are then executed as a field of User-ID in ARC/INFO (Chanlikit, 1991).

In addition, a large number of points have been digitised in point mode in order to produce a variety of vegetation cover map in both urban and suburban areas (Table 4.15).

Table 4.15 The digital data digitised in point mode and transferred to ARC/INFO/TIN environment.

Area	Type of digital map	Digital mode	GIS package
Klong Toei district	Vegetation cover	Point	ARC/INFO
Lad Krabang district	Digital terrain model	Point	ARC/INFO/TIN
	Vegetation cover	Point	ARC/INFO

4.7 THE UTILISATION OF A DIGITISER FOR DATA CAPTURE METHOD
FOR LIS/GIS

Data capture is described as a process for achieving the extraction of relevant data while the related transaction/operation is occurring or a process of collecting data from distributed points at which it has been captured/input as a separate operation (Illingworth, 1990). Normally the resolution (the smallest distance or movement that the digitiser can distinguish) of the commonly used tablet digitisers lies in the range 50-100 microns; the actual accuracy of the X/Y coordinates produced by the device itself will be a little lower. Several digitisers offering a resolution of 25 microns (0.001 inch) but an accuracy of 125 microns (0.005 inch) are sufficient because the tracking accuracy of a trained operator is only about 200 microns or 0.2 mm (Lee, 1991). In this thesis, a flatbed digitiser - Summagraphics 'MICROGRID' providing a resolution of 254 microns or 0.010 inch (Summagraphics Corporation, 1986) - has been used for data capture for obtaining LIS/GIS data which are then used in a proposed schedule for urban land readjustment in Bangkok.

In the Klong Toei project, several maps - in the same spatial reference system (UTM) - with different map scale (eg soil map, geological map, urban facility maps) were manually digitised by means of the flatbed digitiser, as shown in Table 4.16.

Table 4.16 The existing maps which were digitised by using a digitiser in the Klong Toei district.

Area	Type of map	Map scale (1:)
Klong Toei district	Geologic	250,000
	Soil	100,000
	Electricity network	4,000
	Telephone network	4,000
	Water supply network	4,000
	Cadastral	2,000

In the Lad Krabang project, it was determined that the electricity network is the only network which has recently been installed and it is located along the Lum Nai So canal which is perpendicular to the northern part of the study area. Consequently, the location of electricity network was digitised with the help of the flatbed digitiser, as described in Table 4.17.

Table 4.17 The existing maps which were digitised by using a digitiser in the Lad Krabang district.

Area	Type of map	Map scale (1:)
Lad Krabang district	Cadastral	1,000
	Electricity network	4,000
	Future road network	10,000

Finally, the digital data derived by the flatbed digitiser in both urban and suburban areas were transferred to the GIS package (ARC/INFO) for analysing and producing various digital maps.

Chapter 5

DATABASE DESIGN FOR URBAN LAND READJUSTMENT: PRINCIPLES AND APPLICATION FOR BANGKOK

5.1 INTRODUCTION

The aim of this chapter is to explain certain aspects of database design in the context of Bangkok. Section 5.2 deals with the principles of database design in the wider context of GIS. To be effective, the database must be constructed in a form appropriate for each particular task, and the design of the database is a specialist operation. In section 5.3, the current involvement in database management systems (DBMS) is considered with respect to the three main government bodies involved, the Department of Town and Country Planning (DTCP), the National Housing Authority (NHA) and the Bangkok Metropolitan Administration (BMA). Section 5.4 explores the classic conceptual database design of the LIS/GIS data. In section 5.5, different types of DBMS structures and the reasons why the relational database package, ORACLE, has been chosen to be an external hybrid DBMS in this research is discussed. Then the fundamental concept of logical database design is described in the section 5.6, while the physical database design is mentioned in section 5.7. Section 5.8 deals with mapping or transforming LIS/GIS data into the database system. Section 5.9 demonstrates the capability of the structured query language (SQL) in both interactive SQL mode and embedded SQL mode. Finally, in section 5.10, the linkage between graphic data which are stored in the ARC/INFO package and non-graphic data which are mapped in the ORACLE package is described in terms of the database integrator process.

5.2 OVERVIEW OF DATABASE DESIGN PROCESS

Most information systems have a common procedure. They are all developed and undertaken in the same way, and they will all pass through the same classic phases: strategy planning, feasibility, analysis, design, implementation, and maintenance. Some people break down these steps; others combine them because there are many variants possible. The important thing is to form an overview of how a database, which is seen as an integral part of information systems, is developed and utilised in LIS/GIS for the urban land readjustment process. The fundamental design of database is defined by its 'schema' that is the model, or structure around which fields, records, and files are organised. The goals of database design are manifold: to satisfy the information content requirements of the specified users and applications; to provide a natural and easy-to-understand structuring of the information; and to support the processing requirements and any performance objectives such as response time, processing time, and storage space. The database design process consists of six main phases as follows:

- Phase 1: Investigation of current environment.
- Phase 2: Conceptual database design.
- Phase 3: Choice of database management system structure.
- Phase 4: Logical database design.
- Phase 5: Physical database design.
- Phase 6: Database system implementation.

Phase 1 involves the collection of information concerning the intended use of the database. Phase 2 produces a conceptual schema for the database that is independent of a specific DBMS, whereas phase 3 concerns choices of classic DBMSs. Phase 4 deals with mapping or transforming the conceptual schema from the high-level data model such as the Entity-Relationship (E-R) model used in phase 2 into the data model of the DBMS chosen in phase 3. The goal of phase 5 is to design the

specifications for the stored database in terms of physical storage structures, record replacement, and access path, while phase 6 refers to database implementation.

5.3 INVESTIGATION OF CURRENT ENVIRONMENT

With information technology (IT), it is evident that the twentieth century has witnessed the development of a major scientific force. A great amount of data is collected to meet our demand for knowledge, to make use of the natural resources necessary to provide the infrastructure to human life and to cope with our societies. The advances in LIS/GIS during the 1970s and 1980s were directed to data acquisition and capture into computer format, the appropriate management of that data within a computer environment, the analysis of data in various ways and the output of the results. As a tool, LIS/GIS incorporates the development of data models for handling graphic representations of spatial phenomena and the creation of linkages between these models and DBMS. A most significant ground for the development of DBMS is their ability to service the needs of a variety of users. In addition, several DBMS packages do not consist of merely a computer and electronically stored data. Rather, they are systems of processes that can serve the planners by meeting their information requirements for a variety of planning decisions. To achieve this any DBMS has to be flexible both in its structure and the ways in which data are retrieved (Cassettari, 1993). Consequently, the DBMS plays a role as an indispensable tool for more efficient management of an organisation's data resource. In this research, the three prime government agencies - the DTCP, NHA, and BMA - involved in the utilisation of DBMS for urban land readjustment in Bangkok have been investigated as described in section 5.3.1, section 5.3.2, and section 5.3.3 respectively.

5.3.1 The current DBMS in the Department of Town and Country Planning

Although some trained personnel are available in the DTCP and the computer technology has been utilised in modern planning procedure since the early 1980s, as yet this is not enough to cope with the complexity of database management problems in the city planning process. In consequence, some collected attribute data are not effectively integrated into the plan making procedures. Normally, a plan is formulated and based on a series of judgements, and it is important that those judgements be based on an internally consistent information system. Therefore, it is clear that the establishment of an integrated data management system for city planning is an essential task for the improvement of the rationality and efficiency of the planning process. In order to meet this requirement, a DBMS package (dBASE III Plus for a stand-alone personal computer) based on modern computer technology was first used in 1988 in a feasibility study project of land readjustment in Laem Chabang district, Chon Buri province.

In 1990, a dBASE IV for a stand-alone personal computer package was installed for data collection and analysis not only in the comprehensive plan but also in the urban land readjustment process. A GIS package, ARC/INFO, has been in operation for an urban land readjustment case study in Huai Khwang district, Bangkok since 1992. At the time of writing, the Modular GIS Environment (MGE) has also been installed to cope with the two remaining urban land readjustment projects in Pak Kret district, Nonthaburi province and Muang district in Lop Buri province.

5.3.2 The current DBMS in the National Housing Authority

The NHA launched an experimental urban land readjustment project in Lad Krabang district, Bangkok, in late 1992. The NHA has decided to manipulate graphic data by using manual methods and storing non-graphic data (eg land value, current construction cost of public utilities) in a simple DBMS package such as dBASE IV (for a stand-alone personal computer). In fact, this package can more or less meet the present requirements of the NHA because the study area contains simply 28 parcels

of land and for these parcels only a few attribute data have been used for the urban land readjustment analysis, particularly in the process of financial plans.

5.3.3 The current DBMS in the Bangkok Metropolitan Administration

The Bangkok Metropolitan Urban Land Readjustment Committee (BMULRC) is appointed as the highest authority on urban land readjustment. The BMULRC began the first urban land readjustment pilot study in the Bang Khen district, Bangkok, in 1992 and this is continuing at the time of writing, as described in chapter 2, section 2.9.3. The manual method of collecting and capturing graphic data is still applied as a common practice while the attribute data have been analysed by using a popular DBMS package (dBASE IV for a stand-alone personal computer). It is worth noting that there has recently been a Bangkok Land Information System (BLIS) pilot study in Klong Toei district, Bangkok. The pilot study has been executed since 1990 by the BLIS agencies which are composed of the BMA, MEA, MWA, TOT and DOL. One of the aims of the BLIS pilot study is to develop procedures for the integration of both graphic and non-graphic data sets into a common database by means of LIS computer technology. At the time of writing, none of the urban land readjustment projects (in Site 1 and Site 2) is likely to utilise the same technique as has been applied to the BLIS pilot study.

5.3.4 Assessment of current database design for urban land readjustment in Bangkok

In any organisation where many users utilise the same non-graphic data, there is a need for database design focused on identifying the data to be stored in the database and on choosing appropriate structures to represent and store these data. These tasks are mostly undertaken before the database is actually implemented. However, the final database design must be capable of supporting the requirements of all user groups. In addition, an initial distinction should be made between physical and

logical design. Physical design may include considerations such as spreading the database across multiple disk drives to balance input/output load or for security in the event of disk media failure while logical design represents the user's view of the interrelationships between data sets stored in the database. The logical database design and physical database design are further described in chapter 5, section 5.6 and section 5.7 respectively.

The DTCP staff have gained their experience since 1988 through a series of urban land readjustment case studies. Moreover, the JICA experts in Thailand are concentrated on providing both theoretical and practical knowledge of urban land readjustment which can give the DTCP staff a good start toward the implementation of this system in Thailand. Theoretically speaking, the DTCP staff have both gained their skills and developed their skills by means of standard commercial DBMS packages using dBASE III Plus for learning and ARC/INFO for developing their skills. The external hybrid approach has also been recently introduced to the database design procedure. Therefore, there has been no clear failure of current database design within the DTCP to date.

In the Lad Krabang feasibility study, the vivid drawback of using dBASE IV package is that there is no linkage between graphic and non-graphic data, which causes difficulty in data analysis, layout design, and plotting design process. As a result, the NHA has to carry out the layout design and replotting design by means of conventional methods which consume time and man power.

The BMULRC has made a resolution to store non-graphic data of the two study areas (Site 1 and Site 2) in the dBASE IV environment. Consequently, the layout design and replotting design have been done by using traditional procedures.

In summary, the database design in the DTCP has been developed from a standard dBASE III Plus personal computer to a sophisticated method using LIS/GIS

computer technology while the NHA and the BMULRC have preferred to develop analysis methods by means of the standard dBASE IV for stand-alone personal computers rather than generate layout design and replotting design by using LIS/GIS packages. Although these personal computers often present data in tabular form, they lack the full power of a relational DBMS language such as structured query language (SQL). The main problem is the limited memory available under MS-DOS. Moreover, the combination of the operating system, networking software, and data interface often leave little room for the front-end application program.

5.4 CONCEPTUAL DATABASE DESIGN

Data are language, mathematics or other symbols which are generally agreed to represent people, objects, events and concepts (Daniel and Yeates, 1990). Therefore, a database is a collection of interrelated data that are stored in a computerised information system to serve one or more applications and is independent of the computer programs that use it (Huxhold, 1991). Database systems refer to systems that are designed to manage large bodies of information. The management of data involves both the definition of structures for the storage of information and the provision of mechanisms for the manipulation of information. In addition, the database system must provide for the safety of information stored in the database, despite system crashes or attempts at unauthorised access. If data are to be shared among several users, the system must avoid possible anomalous results (Korth and Silberschatz, 1986).

The second phase of database design includes two types of activities. The first activity, so-called 'conceptual design', investigates the data requirements of the database resulting from phase 1 and produces a conceptual database schema in a DBMS and a high-level data model such as the entity-relationship (E-R) model. The second activity, so-called 'transaction design', examines the database application

whose requirements were analysed in phase 1 and produces high-level specifications for these transactions. In the thesis, the DTCP, Thailand, was the organisation selected for consideration of database design because it is considered to be a good representative organisation and a pioneer for undertaking urban land readjustment in Bangkok. Therefore, the conceptual database design will be focused on the DTCP model.

5.4.1 Conceptual database design

In general, a conceptual schema design is made up of three basic components: the entity types, relationship types, and their attributes. The entity is any concrete or abstract object or event in the organisational or user environment, often called the 'real world' (Everest, 1986). It may also be an object with a physical existence - LAND, BUILDING - or it may be an object with a conceptual existence - an OPERATION, an OPERATION_TYPE. Each entity has particular properties, so-called attributes, that describe it. In this thesis, for example, a LAND entity is described by the PARCEL#, OWNER_CODE#, LAND_X and LAND_Y. A particular entity will have a 'value' for each of its attributes. A relationship is a logical association between two (or more) entities. A useful clue for distinguishing between entities and relationships is that an enterprise often uses 'nouns' to describe entities, and 'verbs' to describe relationships (Howe, 1994). Such relationships are represented by connecting lines.

Figure 5.1 is an example of an E-R diagram which shows individual entity occurrences and their relationships. The conventions which will be used in drawing an E-R type diagram are that entity types (eg LAND, LAND_USE, LAND_VALUE, LANDUSE_CODE, BUILDING, OWNER) will be represented by 'rectangular boxes', and relationship types such as SITUATED, EVALUATED, CONTAINED, DIVIDED and BUILDING_OWNERSHIP will be shown in 'diamond-shaped boxes' attached to the participating entity types with straight lines. An entity or relationship

type which is not represented by its own table type (or has no attribute/attributes) will be marked with an ‘asterisk’ on the E-R type diagram.

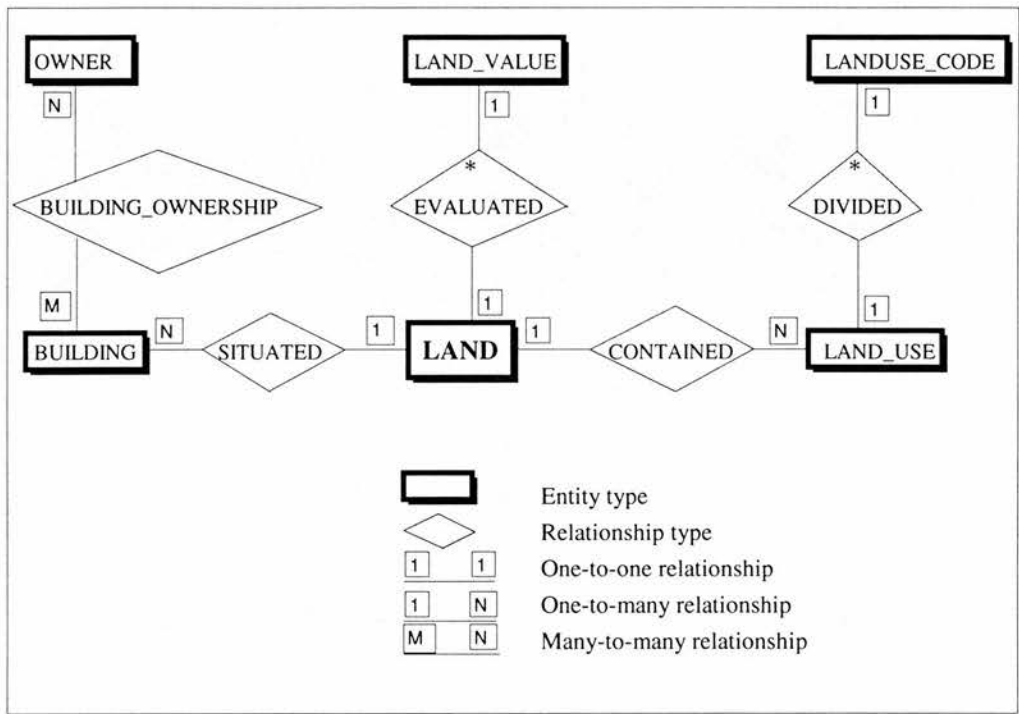


Figure 5.1 An entity-relationship (E-R) type diagram.

A significant property of an entity-relationship model is its ‘degree’. There are three classic types of relationship degree, each corresponding to different pairs of enterprise rules for the relationship (see Figure 5.1).

1) 1:1 (one-to-one) relationship

Enterprise rules between the entities LAND and LAND_VALUE:

- ‘A parcel of land can be evaluated with only one price’.
- ‘Only one value can be attached to a land parcel’.

2) 1:N (one-to-many) relationship

Enterprise rules between the entities LAND and BUILDING:

- ‘A parcel of land can be occupied by many buildings’.

‘A building is situated on a parcel of land’.

3) M:N (many-to-many) relationship

Enterprise rules between the entities OWNER and BUILDING:

‘A person may own many buildings’.

‘A building may be owned by many persons’.

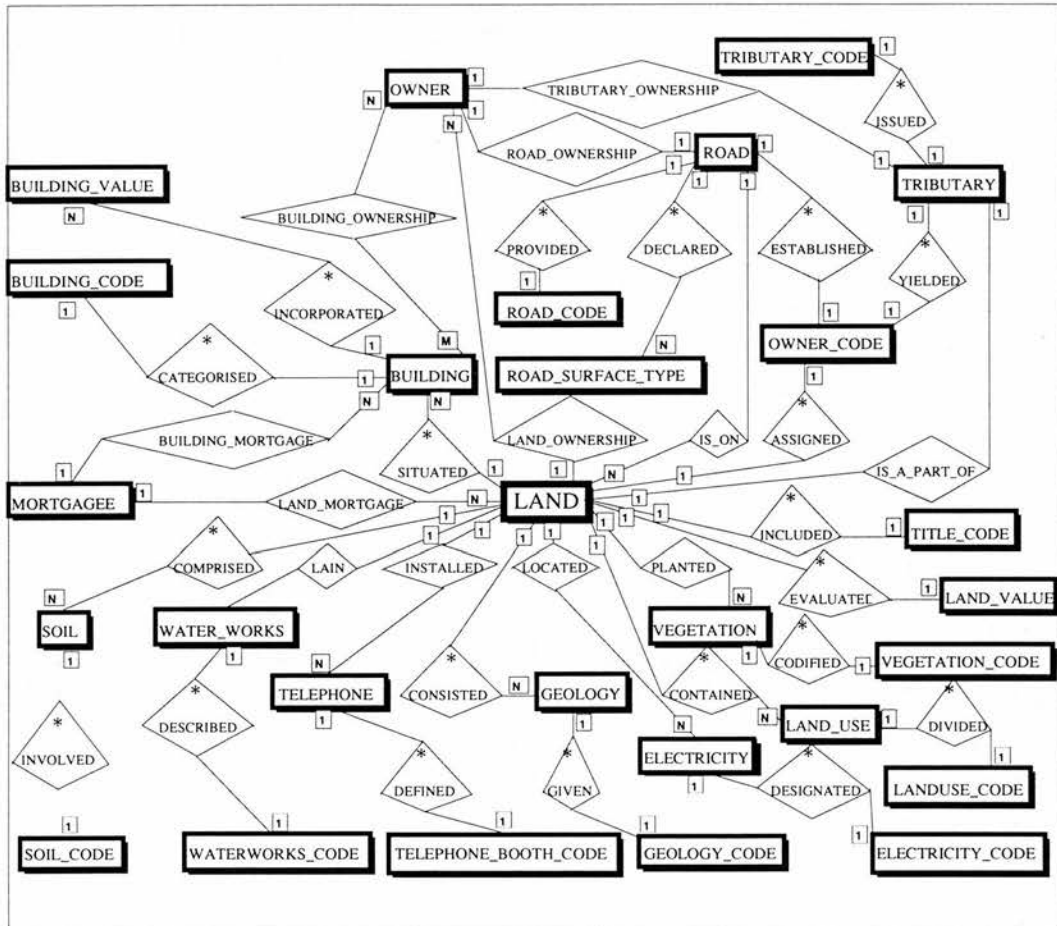


Figure 5.2 The proposed E-R model of LIS/GIS data for urban land readjustment in Bangkok.

By means of these rudimentary concepts, it is possible to generate sophisticated relationships between types of data related to land for executing urban land readjustment in Bangkok. The availability of diagramming methods linked to the conceptual schema designs allows graphical representations of E-R models to be

drawn, as shown in Figure 5.2. The models are designed logically through a land-based approach where land-based features (eg buildings, roads, soils, vegetation) are related to each other and linked to the land. For example, BUILDING is related closely to OWNER and MORTGAGEE entities; they all are linked to the LAND entity.

5.4.2 Transaction design

The execution of a program (or application) that accesses or changes the contents of a database causes what are called 'database transactions'. Database transactions are the discrete packets of information passed between the database and the application (that is queries and results). In a multiuser DBMS, the same database records may be accessed and updated concurrently by user programs. This may lead to problems such as an inconsistent database if this concurrent execution is uncontrolled. Therefore, a main part of database design is to specify the functional characteristics of these transactions early on in the design procedure. This certifies that the database schema incorporates all the information needed by these transactions.

Transactions normally can be classified into three groups: retrieval transactions, update transactions, and mixed transactions (Elmasri and Navathe, 1994). Retrieval transactions are exercised to retrieve and display data on a screen or for producing a report, for example, listing all trees on a given land parcel. Update transactions are utilised to enter new data or modify existing data in the database, for instance, adding the new location of a coconut tree in a particular land parcel. Mixed transactions are used for more complex applications that include some retrieval and some update. An example of mixed transactions may first display all trees (bamboo, coconut, and mango tree) on a given land parcel, and then update the database, such as selecting all coconut trees and deleting a particular one.

Transaction design is as important as conceptual schema design. As a result, the most crucial transactions are best known in advance of system implementation and should always be specified at an early stage.

5.5 CHOICE OF DATABASE MANAGEMENT SYSTEM STRUCTURE

A DBMS consists of a collection of interrelated data and a set of programs to access those data. Normally the collection of data is referred to as the database. The database contains information about one particular enterprise. The main aim of a DBMS is to provide an environment that is both convenient and efficient to use in retrieving information from and storing information into the database. Moreover, typical functions of a DBMS include the logical and physical linkage of related data elements, the verification of data values, and other data management functions such as security, archiving, and updating. Database management systems can be categorised by the method that they use to structure their data internally. These systems generally fall into four main categories:

- inverted list DBMS,
- hierarchical DBMS,
- network DBMS,
- relational DBMS.

5.5.1 Inverted list DBMS

The rudimentary storage mechanism for data in this DBMS structure is by use of tables/files containing rows (records) and columns (fields), as shown in Figure 5.3. As each new item is added to the database, it is simply placed at the end of the table, which gets longer and longer (Burrough, 1994). Inverted list DBMS incorporate:

LAND						
PARCEL#	OWNER_CODE#	TITLE_CODE#	LAND_X	LAND_Y	OFFICIAL_AREA	LANDVALUE
1	1000	1	1451367	2345127	200	4000
2	1000	1	1451339	2348269	150	4500
3	2000	2	1451201	2346248	300	5000

Key field

Figure 5.3 An inverted list DBMS of a LAND database.

Sequential search - Inverted list DBMS are normally ordered sequentially by the values in a field designated as a key. This would make a parcel number search on the LAND table fast because parcel number (PARCEL#) is a key; however, the entire table must be resequenced in order to find the records with a particular owner, because OWNER_CODE# is not designated as a key.

Binary search - Tables sequenced by the values in the key field can be searched much more rapidly by means of a binary search technique that starts at the middle of the table rather than at the beginning. It compares the value of the key in that record with the desired value for a 'greater than' or 'less than' condition and eliminates for consideration the half of the table in which the desired record could not be stored. It continues halving the records for consideration until the desired record is found.

Indexed search - An index is a separate table containing the key of every record and address pointing to the location of the data record for each key. The address is the location on the physical storage device used and is assigned by the software that controls the device. The index is then sequenced, and a search is used on the index rather than on the data file. Additionally, if a new record is added to the table it can be added at the end without resequencing the entire table - only the index need be sequenced. Indexed tables allow access by more than one key; however, they require a considerable amount of expense to keep the indices updated when records are added and deleted, and when values in the records change over time.

In summary, inverted list DBMS are generally very fast and efficient for retrieving data but very slow for data maintenance; their capabilities are severely limited and offer little flexibility. The reason that data maintenance is slow is that every time a record is added, modified, or deleted each participating inverted list must be updated.

5.5.2 Hierarchical DBMS

Hierarchical-structured DBMS are sometimes referred to as tree-structured DBMS because as the data records spread out under the main record, they resembles roots spreading out under a tree. In a hierarchical DBMS, there is more than one type of record in the database, Figure 5.4.

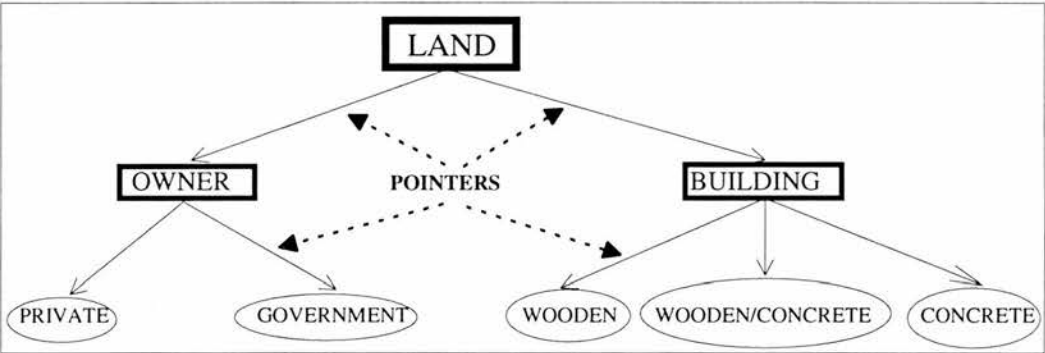


Figure 5.4 A hierarchical DBMS of LAND, OWNER, and BUILDING databases.

One type of record is designated as a ‘parent’ or LAND table, and it can be associated with any number of ‘children’ or OWNER tables through internally assigned ‘pointers’. The OWNER table can also have ‘children’ associated with them, with additional pointers assigned for the third level of association. The outstanding characteristic of these hierarchical data structures is that each record has one higher-level record associated to it and this is generally known as 1:N or ‘one-to-many’ relationship between two record types. An occurrence of the one-to-many relationship type consists of one record (1-side) of the parent record type and a number of records (N-side) of the children record type. In LAND table, the linking of each parcel record to the landowner records associated with it is accomplished by

pointers assigned by the database management software when each detail record is created. Hierarchical DBMS are not only easy to understand and update but they also can provide high speed access to large data sets.

While the hierarchical DBMS provide some flexibility in relating data between records, there are some limitations in using hierarchical files in the DBMS:

- Data in the OWNER table can only be accessed by first accessing the LAND table to which they are linked.
- Deleting a certain detail (eg PARCEL#) from the LAND table also deletes all outstanding details in the OWNER table.
- Data relationships are difficult to modify and queries are restricted to traversing the existing hierarchy.

In general, the hierarchical approach is very efficient for searching if all desired access paths follow the parent-child linkages. Nevertheless, 'many-to-many' (M:N) relationships do not fit naturally into the structure and extensive pointer systems are required to deal with them. The combination of inflexible structure and the expenses of maintaining or changing pointer systems make extensive modification of the structure of hierarchical systems, to meet new requirements, a resource intensive operation. These reasons result in the lack of adoption of this type of DBMS for flexible LIS/GIS requirements.

5.5.3 Network DBMS

The structure of a network DBMS is essentially the same as that of a hierarchical DBMS except that a 'child' in a data relationship has more than one 'parent'. In the network data model, an entity can have multiple parents as well as multiple child relations and no root is required. In consequence, data records can be directly searched without traversing the entire hierarchy above that record. The network is established by using 'pointers' that link records between related files. The 'many-to-many' relationship allows more than one record in a file to be associated with more

than one record in another file, Figure 5.5. For example, the OWNER table contains records of parcel data, and some parcels are owned by more than one person. This is a many-to-many relationship, which network data structures accommodate better than hierarchical structures.

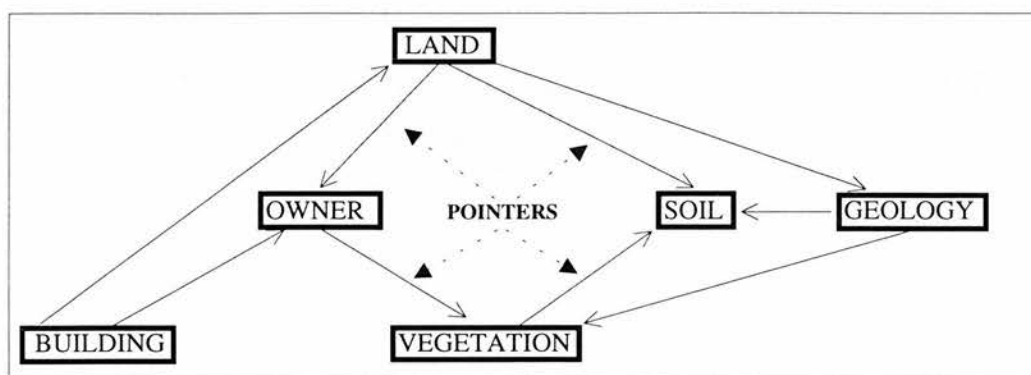


Figure 5.5 A network DBMS of LAND, OWNER, SOIL, GEOLOGY, BUILDING, and VEGETATION databases.

As the utilisation of the database expands by adding new applications and by providing responses to new types of data inquiries, the logical linkages among data fields tend to multiply, causing a high degree of complexity in managing the pointers within the network. Major restructuring of database may be time consuming because of the extensive pointer structures that have to be rebuilt. The network approach is considered to be powerful, flexible, fast, and efficient in terms of central processing unit resources but it may be comparatively difficult to set up the database correctly. From the implementation point of view, moreover, it may also be complex and confusing for less expert users. Healey (1991) advocates the idea that the network DBMS would have found ready application in certain areas, such as work involving both GIS and location analysis, where problems may fit quite naturally into the network structure. While important examples of this can be found, it appears that the disadvantages of network systems from the user's viewpoint continue to militate against their widespread use in GIS.

5.5.4 Relational DBMS

The concept of relational database management systems (RDBMS) has been proposed by Codd and has become extremely popular in recent years. The fundamental model on which the RDBMS are based is very easy to understand, and it typically allows tables (or so-called ‘relation’) to be joined dynamically to create new relations that a user requires to support new applications (Montgomery and Schuch, 1993). Normally a table consists of rows, columns, and cell entries (Laurini and Thompson, 1992), as shown in Figure 5.6. Each row in the table is generally referred to as either a ‘record’ or ‘tuple’ (Dates, 1981). In this thesis, however, the author will use the two terms ‘tuple’ and ‘row’ interchangeably. Each column, which has a unique name within a tuple, is called a ‘field’ or an ‘attribute’ (Star and Estes, 1990). Again, the author will use the two terms ‘attribute’ and ‘column’ interchangeably.

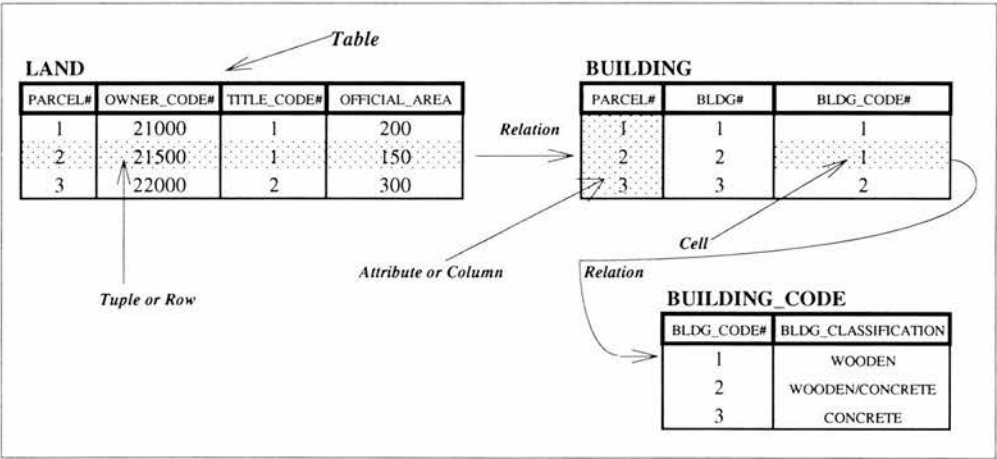


Figure 5.6 A relational DBMS of LAND, BUILDING, BUILDING_CODE databases.

Without pointers to manage, new relationships between data items can be created by the user rather than by depending on a computer programming specialist to establish the associations. In addition, the user can define the relation that is appropriate for the query. This relation is not necessarily already presented in the existing tables, so the controlling program uses the methods of relational algebra to construct the new tables. RDBMS have the significant advantage that their structure is very flexible and

can meet the demands of all queries that can be formulated using the rules of Boolean logic and mathematical operations. They also allow different kinds of data to be searched, combined, and compared. Addition or removal of data is easy too, because this just involves adding or removing a tuple. Examples of RDBMS are DB2, dBASE IV, INFORMIX, INGRES, ORACLE, QBE, and SYBASE. In this thesis, the ORACLE package, version 6.2, has been used both in the Klong Toei project and the Lad Krabang project, Bangkok, and the main reason for using ORACLE is because the package provides high 'data integrity' which is considered to play a crucial role in handling non-graphic data for LIS/GIS.

Enforcement of data integrity (or consistency and correctness of the data) in the database is one of the most important tasks undertaken by a DBMS. Normally, RDBMS packages can take care of data integrity if 'integrity rules' (or constraints) are defined. The integrity rules are the rules with which the contents of database must comply at all times, and they describe which updates to the database are permitted (van der Lans, 1992). The integrity rules not only have several forms but they are also used very frequently. That is why they have special names: primary key, candidate key, alternate key, and foreign key.

Primary key - The primary key of a table is composed of one or more columns that can be used for uniquely identifying rows in the table. In other words, two different rows in a table may never have the same value in their primary key, and for every row in the table the primary key must have a value. The PARCEL# column in the LAND table is the primary key for this table. Two parcels, therefore, may never have the same number and there may never be a parcel without a number.

Candidate key - Some tables contain more than one column (or combination of columns) that can act as a primary key. Those columns, including the primary key, that possess all the properties of a primary key are called 'candidate keys'. Because a table must possess a primary key, it always has a minimum of one candidate key. If it

is assumed that in the BUILDING table, the PARCEL# and BLDG# of each parcel are a unique combination, then these columns exist as a candidate key. This combination of two columns could also be designated as the primary key.

Alternate key - A candidate key which is not the primary key of a table is called an alternate key. The term candidate key is a general term of all primary and alternate keys. The columns PARCEL# and BLDG# from the BUILDING table are possible alternate keys.

Foreign key - A foreign key is a column (or combination of columns) in a table in which the population is a subset of the population of a primary key of a table. For example, the BLDG_CODE# column is called the primary key of the BUILDING_CODE table. The BLDG_CODE# column in the BUILDING table represents a subset of the BLDG_CODE# column in the BUILDING_CODE table. Therefore, BLDG_CODE# in the BUILDING table is defined as a foreign key.

In summary, there is no requirement for pointers or linkages between data records to be set up, as was the case with hierarchical or network systems, because relationships between entities are directly represented as tables. Beyond that RDBMS are characterised by simplicity, in that all data are represented in tables of rows and columns. From the database design viewpoint, entity-relationship modelling fits very closely with relational systems. Unlike other types of database, relationship sets describing many-to-many (M:N) relationships between entity sets are also represented by a table of data values.

5.5.5 Choosing a DBMS package

In this thesis, relational database management system software, ORACLE version 6.2, has been selected and implemented as an external DBMS because the package

can support promising, efficient and effective solutions for the major LIS/GIS database features, including:

1. Manageable security - To protect against unauthorised database access and use, the software provides fail-safe security features to limit and monitor data access. These features make it easy to manage LIS/GIS data including even the most complex design for data access.
2. Database integrity - The software enforces data integrity, 'business rules', that dictate the standards for acceptable data. Consequently, the cost of coding and managing checks in many database applications is eliminated.
3. Compatibility - The ORACLE software is compatible with industry standards, including most industry standard systems. Applications developed for the software can be exercised on virtually any system with little or no modification.

5.6 LOGICAL DATABASE DESIGN

Normally logical database design seeks to develop a detailed description of a database that will meet the needs of all users and application processes expected to use the database now or in the future because both anticipated and unanticipated uses of the database should influence the design. It is also necessary for the designer to identify the real world entities about which information is to be collected and stored, the attributes of those entities, and the relationships among the various entities and attributes. In this thesis, it is crucial to capture the essential aspects of the conceptual database design, so-called 'phase 2', from the E-R model which has already been executed (see Figure 5.2). Consequently, in the logical database process (so-called 'phase 4'), the E-R model has been mapped into the chosen relational database management system package, as described in chapter 5, section 5.5.5. The mapping can proceed in three stages:

- Normalisation,
- Key attributes of a table,

- Converting 3NF tables to logical data structures.

5.6.1 Normalisation

Normalisation can be defined as the process of transforming unstructured tables of data through a series of refined normal forms to produce a set of simple, unambiguous relations which are free of redundant data. Undesirable features caused by redundant data include additional processing of duplicated data, potential inconsistency of data and update anomalies (Skidmore *et al.*, 1992).

The general idea of normalisation is that at each successive stage of normalisation certain undesirable features are eliminated from the initial unnormalised table. The normalisation process is often described in terms of stages known as first, second, third, fourth, and fifth normal forms (1NF-5NF). Unnormalised tables are converted to first normal form (1NF) by removing repeating groups into separate tables. Second and third normal forms (2NF and 3NF) are achieved by reducing and splitting tables so that the only functional dependencies which exist are between the primary keys and the remaining non-key attributes. Fourth normal form (4NF) deals with multi-valued determinacies and fifth normal form (5NF) deals with a rather unusual situation known as join dependency which is of little practical significance (Howe, 1994). It is noted that the fourth and fifth normal forms are beyond the scope of this thesis.

1) Unnormalised form (UNF)

The first stage in normalisation is to classify the group of data items to be normalised and to pick a key which will identify each occurrence of the group uniquely. The UNF tables will include all data items, and need to be indicated in the UNF table by indenting or level numbers. The level numbers have been chosen to be indicated in the UNF table of non-graphic data which play a significant role in the urban land readjustment process in Bangkok, as shown in Table 5.1.

Table 5.1 The classification of data items to be in unnormalised form (UNF).

UNF	LEVEL
PARCEL#	1
OWNER_CODE#	1
TITLE_CODE#	1
LAND_X	1
LAND_Y	1
OWNER_CLASSIFICATION	1
TITLE_CLASSIFICATION	1
OWNER#	2
OFFICIAL_AREA	2
LAND#	2
TITLE_SERIAL#	2
VOLUME	2
PAGE	2
DOL_SHEET	2
UTM_SHEET	2
UTM_SERIES	2
GENDER	2
OWNER_INITIAL	2
OWNER_SURNAME	2
OWNER_ADDRESS	2
OWNER_DISTRICT	2
OWNER_POSTCODE	2
OWNER_PROVINCE	2
OWNER_TEL#	2
MORTGAGEE#	3
LMORT_DATE	3
LMORT_AMOUNT	3
SEX	3
MORTGAGEE_INITIAL	3
MORTGAGEE_SURNAME	3
MORTGAGEE_ADDRESS	3
MORTGAGEE_DISTRICT	3
MORTGAGEE_POSTCODE	3
MORTGAGEE_PROVINCE	3
MORTGAGEE_TEL#	3
LANDVALUE_YEAR	4
LANDVALUE	4

2) First normal form (1NF)

A table is in 1NF if it contains no repeating groups. The UNF table of non-graphic data has been removed to form a table of its own, and give it a ‘primary key’

(PARCEL#) consisting of the primary key of the parent UNF table plus an additional attribute or attributes to enable unique identification of its rows, as depicted in Appendix 5.1. By including the primary key (PARCEL#) of the parent table in the four new tables, the links between them are maintained.

3) Second normal form (2NF)

A table is in 2NF if it contains no non-key attributes which are dependent on only part of the primary key. Any such attributes in the 1NF tables are removed to form a new table with the relevant partial key as its primary key. In Appendix 5.1, a set of attributes (GENDER, OWNER_INITIAL, OWNER_SURNAME, OWNER_ADDRESS, OWNER_DISTRICT, OWNER_POSTCODE, OWNER_PROVINCE, and OWNER_TEL#) are dependent solely on OWNER#, which is only part of the second table (LAND_OWNERSHIP) in the 1NF. To achieve 2NF, these partially dependent attributes have to be removed to form a new table (OWNER).

4) Third normal form (3NF)

A table is in 3NF if there are no non-key attributes which depend on other non-candidate key attributes. Any such dependent attributes are removed from the 2NF table to form a new table having the attributes that determines them (their determinant) as its primary key. The determinant is left in the parent table as a 'foreign key', in order to maintain links between the data (Weaver, 1993). In Appendix 5.1, the table (in 2NF) with a primary key of PARCEL# contains an attribute (OWNER_CLASSIFICATION), which is dependent directly on OWNER_CODE#, rather than the primary key of PARCEL#. Therefore, removing OWNER_CLASSIFICATION attribute to form a new table (OWNER_CODE) with OWNER_CODE# is needed, leaving OWNER_CODE# behind as a foreign key in the parent table. Applying the same procedure to TITLE_CODE# and TITLE_CLASSIFICATION attributes, the new table (TITLE_CODE) has then been formed in the 3NF.

In the thesis, there are 40 tables/relations after determining the 3NF which are composed of several attribute data, for example, LAND, BUILDING, VEGETATION, LAND_USE, SOIL, GEOLOGY (see Appendix 5.1). The related non-graphic data of LIS/GIS for urban land readjustment will be populated in the phase 6 (Database system implementation).

5.6.2 Key attributes of a table

A table/relation is defined as a set of tuples. By definition, all elements of a set are distinct; therefore, all tuples in a table must also be distinct. This defines that no two tuples can have the same combination of values for all their attributes. In Appendix 5.1, the LAND table incorporates a set of attributes: PARCEL#, OWNER_CODE#, TITLE_CODE#, LAND_X, LAND_Y. The attribute set PARCEL# is considered to be a key of the LAND because there are no two land parcel tuples that will ever have the same value for PARCEL#. As a result, the PARCEL# value '1' identifies uniquely the tuple in the LAND table.

Generally speaking, a table may have more than one key. In this case, PARCEL#, OWNER_CODE#, and TITLE_CODE# in the LAND table are called 'candidate keys'. However, it is common to designate one of the candidate keys (PARCEL#) as the primary key, and the remaining key (OWNER_CODE# and TITLE_CODE#) are selected to be the foreign keys of the table. In this research, the primary key of the table will be denoted by an 'underline' while the foreign key will be underlined and also annotated with an 'asterisk'. A few examples of the conceptual models corresponding to the Appendix 5.1 are illustrated below, while the full details are shown in Appendix 5.2.

LAND (PARCEL#, *OWNER_CODE#, *TITLE_CODE#, LAND_X,
LAND_Y).

OWNER (OWNER#, GENDER, OWNER_INITIAL, OWNER_SURNAME,
OWNER_ADDRESS, OWNER_DISTRICT,
OWNER_POSTCODE, OWNER_PROVINCE,
OWNER_TEL#).

LAND_OWNERSHIP (PARCEL#, OWNER#, OFFICIAL_AREA, LAND#,
TITLE_SERIAL#, VOLUME, PAGE, DOL_SHEET, UTM_SHEET,
UTM_SERIES).

5.6.3 Converting 3NF tables to logical data structures

The principal objective of logical database design in phase 4 is to achieve the logical data structures using the results of the E-R models (in phase 2) and data items of 3NF tables which have already been enforced by normalisation. The conversion process is a fairly manual one, following 4 basic steps:

1. Represent each table corresponding to Appendix 5.2 as an entity type box. It is also helpful to list primary, foreign, (and attributes) inside the box.
2. Underline the primary and foreign key and simply annotate the foreign key elements with an asterisk. Ignore the E-R types (diamond-shaped box with an asterisk), derived from phase 2, which have no attribute elements.
3. For each attribute element of every compound key, check that an entity exists which has that element as its primary key.
4. Add a master-detail relationship between every pair of entities corresponding to the E-R models (eg 1:1, 1:N, and M:N relationship) in phase 2, section 5.4.1.

The result of this phase (Figure 5.7) should be a linkage of conceptual models between entities in the database system. The conceptual models will be later utilised as guidance to create database schemas and database files in the phase 6 (Database system implementation).

5.7 PHYSICAL DATABASE DESIGN

As the main emphasis of this thesis is on logical database design, the author will discuss physical database design only briefly because this is concerned with how the databases are stored on physical devices rather than how they appear to the user.

Physical database design follows logical database design and is the process of developing an efficient, physical storage database structure (McFadden and Hoffer, 1985). It is also the process of choosing access paths for the database files to achieve good performance for the various database applications. Each DBMS will offer a variety of options for file organisation and access paths. These usually include clustering of related records on disk blocks, linking related records via pointers, and various types of fast access to records (hashing). Various types of indexes to records are also chosen, as are placements of logical records in physical files (Hawryszkiewicz, 1994). Once a specific DBMS is chosen, the physical database design process is restricted to choosing the most appropriate structures for the data files from among the options offered by that DBMS.

The result of the physical database design phase is an initial determination of storage structures and access paths for the database files. It is almost always necessary to tune the physical database design on the basis of its observed performance after the database system is implemented. As the database system requirements change, it is often necessary to reorganise some files by constructing new indexes or by altering primary access methods.

5.8 DATABASE SYSTEM IMPLEMENTATION

After the logical and physical database designs are completed, the database system can be implemented. Conceptual models of the selected DBMS are compiled and

used to create the database schemas and database files. The database can now be 'loaded' (or 'populated') with various types of data by using an interactive application processor (IAP), for example, ORACLE SQL *Forms version 3.0. The SQL *Forms is a screen data entry that can be used with a wide variety of CRT terminals. It can be handled to enter data, retrieve data, and modify data in an ORACLE database (Bisland, 1989), as depicted in Plate 5.1.

VEGETATION_CODE	VEGETATION_CLASSIFICATION
1	BAMBOO
2	COCONUT
3	MANGO

Count: =0

<Replace>

Plate 5.1 The pop-up field editor in SQL *Forms environment.

Moreover, the SQL *Forms application has certain 'default' functionality, such as the ability to validate data types, perform navigation throughout a form, and access the database (Bond, 1991). If data have to be converted from an earlier computerised system, 'conversion routines' may be needed to reformat the data for loading into the new database. Also, specifications for programs to access the database can be formulated during implementation design.

The basic procedure for ‘mapping’ (or ‘transforming’) a logical database design process in phase 4 into an indexed implementation is quite straightforward. The following examples, drawn from those discussed in chapter 5, section 5.4.1 (conceptual database design), illustrate the mapping procedure for 1:1, 1:N, and M:N relationships, and also show samples of application program coding for typical transactions. In ORACLE version 6.2, each table can have up to 255 columns. Specifying a data type for a column is mandatory. The package provides six ‘basic data types’: NUMBER, CHAR, LONG, DATE, RAW, LONG RAW. It also supports the following ‘derived data types’: SMALLINT, INT, INTEGER, DECIMAL, DOUBLE PRECISION, REAL, FLOAT, VARCHAR, CHARACTER and LONG VARCHAR, all of which are internally converted by ORACLE to one of the basic data types above. The table 5.2 shows the internal conversion performed by ORACLE.

Table 5.2 An internal conversion from derived data type to basic data type executed by using ORACLE.

Derived data type	Basic data type
CHARACTER (l)	CHAR (l)
DECIMAL (p, s)	NUMBER (p, s)
DOUBLE PRECISION	NUMBER (38)
FLOAT	NUMBER (38)
INT	NUMBER (38, 0)
INTEGER	NUMBER (38, 0)
LONG VARCHAR	LONG
REAL	NUMBER (p, s)
SMALLINT	NUMBER (38, 0)
VARCHAR (l)	CHAR (l)

(l = long, p = precision, s = scale)

The CREATE TABLE statement is used to create database schemas, database files and set up tables in which rows of data can be stored. Examples of CREATE TABLE statements for creating several tables in the LIS/GIS database for urban land readjustment in Bangkok are now given.

5.8.1 Relationships of 1:1 type

According to Figure 5.7 in phase 4, every land parcel has a certain value in a specified year. Therefore, data set of conceptual models of LAND and LAND_VALUE tables are:

- LAND (PARCEL#, OWNER_CODE#, TITLE_CODE#, LAND_X, LAND_Y),
- LAND_VALUE (PARCEL#, LANDVALUE_YEAR, LANDVALUE).

The CREATE TABLE statements for creating the LAND and LAND_VALUE tables can be mapped as follows:

```
CREATE TABLE LAND
    (PARCEL#                NUMBER(3) NOT NULL,
    OWNER_CODE#            NUMBER(6) NOT NULL,
    TITLE_CODE#            NUMBER(1) NOT NULL,
    LAND_X                 NUMBER(6) NOT NULL,
    LAND_Y                 NUMBER(7) NOT NULL),
    PRIMARY KEY (PARCEL#)
    CONSTRAINT LAND_PRIM,
    FOREIGN KEY (OWNER_CODE#)
    REFERENCES OWNER_CODE
    CONSTRAINT LAND_FOR_OCODE,
    FOREIGN KEY (TITLE_CODE#)
    REFERENCES TITLE_CODE
    CONSTRAINT LAND_FOR_TCODE);

CREATE TABLE LAND_VALUE
    (PARCEL#                NUMBER(3) NOT NULL,
    LANDVALUE_YEAR         NUMBER(4) NOT NULL,
    LANDVALUE              NUMBER(6) NOT NULL,
    PRIMARY KEY (PARCEL#, LANDVALUE_YEAR));
```

5.8.2 Relationships of 1:N type

One of the rational ideas in designing a LIS/GIS database is to relate one-to-many relationship between two tables (eg LAND and LAND_USE) where a land parcel has one or more than one land use classification. As a result, the data set of conceptual models of the tables are:

- LAND (PARCEL#, *OWNER_CODE#, *TITLE_CODE#, LAND_X, LAND_Y),
- LAND_USE (PARCEL#, LANDUSE_YEAR, *LANDUSE_CODE#).

The CREATE TABLE statements for constructing the LAND and LAND_USE tables can take the following forms:

```
CREATE TABLE LAND
    (PARCEL#                NUMBER(3) NOT NULL,
    OWNER_CODE#            NUMBER(6) NOT NULL,
    TITLE_CODE#            NUMBER(1) NOT NULL,
    LAND_X                 NUMBER(6) NOT NULL,
    LAND_Y                 NUMBER(7) NOT NULL),
    PRIMARY KEY (PARCEL#)
    CONSTRAINT LAND_PRIM,
    FOREIGN KEY (OWNER_CODE#)
    REFERENCES OWNER_CODE
    CONSTRAINT LAND_FOR_OCODE,
    FOREIGN KEY (TITLE_CODE#)
    REFERENCES TITLE_CODE
    CONSTRAINT LAND_FOR_TCODE);.
```

5.8.3 Relationships of M:N type

With reference to BUILDING and OWNER tables, the many-to-many relationship can be described as one owner possesses many buildings as well as, at the same time,

a building may be owned by many owners. Hence, the data set of conceptual models of the tables is as follows:

- BUILDING (PARCEL#, *BLDG#, *BLDG_CODE#, BLDG_X, BLDG_Y),
- OWNER (OWNER#, GENDER, OWNER_INITIAL, OWNER_SURNAME, OWNER_ADDRESS, OWNER_DISTRICT, OWNER_POSTCODE, OWNER_PROVINCE, OWNER_TEL#).

The CREATE TABLE statements for creating the BUILDING and OWNER table can be defined as follows:

CREATE TABLE BUILDING

```
(PARCEL#                NUMBER(3) NOT NULL,
BLDG#                   NUMBER(3) NOT NULL,
BLDG_CODE#              NUMBER(2) NOT NULL,
BLDG_X                  NUMBER(6) NOT NULL,
BLDG_Y                  NUMBER(7) NOT NULL,
PRIMARY KEY (PARCEL#, BLDG#),
FOREIGN KEY (BLDG_CODE#)
REFERENCES BUILDING_CODE
CONSTRAINT BUILDING_FOR_BCODE);
```

CREATE TABLE OWNER

```
OWNER#                  NUMBER(3) NOT NULL,
GENDER                  CHAR(1),
OWNER_INITIAL           CHAR(20) NOT NULL,
OWNER_SURNAME           CHAR(20) NOT NULL,
OWNER_ADDRESS           CHAR(20),
OWNER_DISTRICT          CHAR(15),
OWNER_POSTCODE          NUMBER(5) NOT NULL,
OWNER_PROVINCE          CHAR(15),
OWNER_TEL#              NUMBER(10),
PRIMARY KEY (OWNER#)
```

CONSTRAINT OWNER_PRIM);.

Once the transactions are ready and the data are loaded into the relational database (the ORACLE), the design and implementation phase is ended and the operational phase of the database system is ready to commence.

5.9 STRUCTURED QUERY LANGUAGE (SQL)

Structured query language (SQL) is a tool for collecting, managing and retrieving data stored by a computer database. SQL is a non-procedural language that users employ to interact with a database, and it works only with relational databases. By non-procedural language, it is meant that users have simply to specify which data they want and not how those data must be found. It is noted that languages such as Ada and C are examples of procedural languages. SQL is considered to be far more than a query tool, although that was its fundamental purpose and retrieving data is still one of its most crucial functions. In this research, a relational database management system package, ORACLE version 6.2, has been chosen to support promising solutions to cope with the LIS/GIS data. The package can usually be used in two ways: interactive and embedded SQL.

5.9.1 Interactive SQL

SQL is functioned as an interactive query language that gives users ad hoc access to stored data. Using SQL interactively, a user can get answers even to complex questions in minutes or seconds, in sharp contrast to the days or so it would take for a programmer to write a custom report program. In other words, an SQL statement is entered on the computer and processed for an immediate result. Because of SQL's ad hoc query power, data are more accessible, and can be used to help city planners make better and more sensible decisions. A SQL statement is rather straightforward and uses simple language, as the following example demonstrates:

```

SELECT VEGETATION#, VEGETATION_COST
      FROM VEGETATION, VEGETATION_CODE
      WHERE VEGETATION_HEIGHT > 7
      AND VEGETATION_SIZE = 'MEDIUM'
      AND VEGETATION_CLASSIFICATION = 'BAMBOO'
      ORDER BY VEGETATION#.

```

The query above has been done by using a relational join. The concept of the join is defined as a SELECT statement, where the FROM clause contains two tables and where the WHERE clause contains a condition which compares the columns of different tables. It is this join operator that allows queries to be performed across multiple tables.

5.9.2 Embedded SQL

With embedded SQL, statements are included in the program which has been written in another programming language. The statements and functional possibilities of interactive and embedded SQL are almost the same. Therefore, most statements that can be entered and processed interactively can also be included in an ORACLE program as embedded SQL. The ORACLE database management software supports amongst other languages: C, COBOL, FORTRAN, PASCAL, and PL/I. These languages are known as 'host languages'. The results of the embedded SQL statements are not immediately visible to user, but are processed by the enveloping program (van der Lans, 1992).

Embedded SQL statements incorporate data definition statements (DDL), data manipulation statements (DML), and transaction control statements within a procedural language program. They are used with the ORACLE precompilers. Embedded SQL statements allow the user to do the following:

- Define, allocate, and release cursors (DECLARE CURSOR, OPEN, CLOSE).

- Declare a database name and connect to ORACLE (DECLARE DATABASE, CONNECT).
- Assign variable names, initialise descriptors, and specify how error and warning conditions are handled (DECLARE STATEMENT, DESCRIBE, WHEREVER).
- Parse and execute SQL statements, and retrieve data from the database (PREPARE, EXECUTE, EXECUTE IMMEDIATE, FETCH).

To do this, SQL statements are embedded directly into the program's source code, intermixed with the other programming language statements. Special embedded SQL statements are used to retrieve data into the program. A special SQL precompiler accepts the combined source code and, along with other programming tools, converts it into an executable program (Groff and Weinberg, 1990). In this thesis, in order to write a program that accesses a database, the author has to start with a conventional programming language, such as C or FORTRAN and then add to the programs as shown in Appendix 5.3 and Appendix 5.4 respectively. The results derived from the both Appendices yield the same solution as in chapter 5, section 5.9.1. Apart from the advantage of procedural capacity, embedded the SQL in a host program has also a significant effect in optimising the processing of the SQL statement.

5.10 DATABASE INTEGRATOR

Several powerful commercial DBMSs (eg DB2, INFORMIX, ORACLE) with different types of platforms (PC's, Workstation) are currently available and in use with a variety of applications. These DBMS are utilised to cope with large, multi-user, concurrent access databases. With ARC/INFO, it is possible to join the non-graphic data relationally in DBMS tables to geographic features (or graphic data). The module that supports this significant functionality is called 'data integrator'. As a matter of fact, INFO could be removed from the ARC/INFO configuration and the

database integrator would function identically. Feature attribute tables are simply managed by ARC/INFO in a format which is also available to INFO.

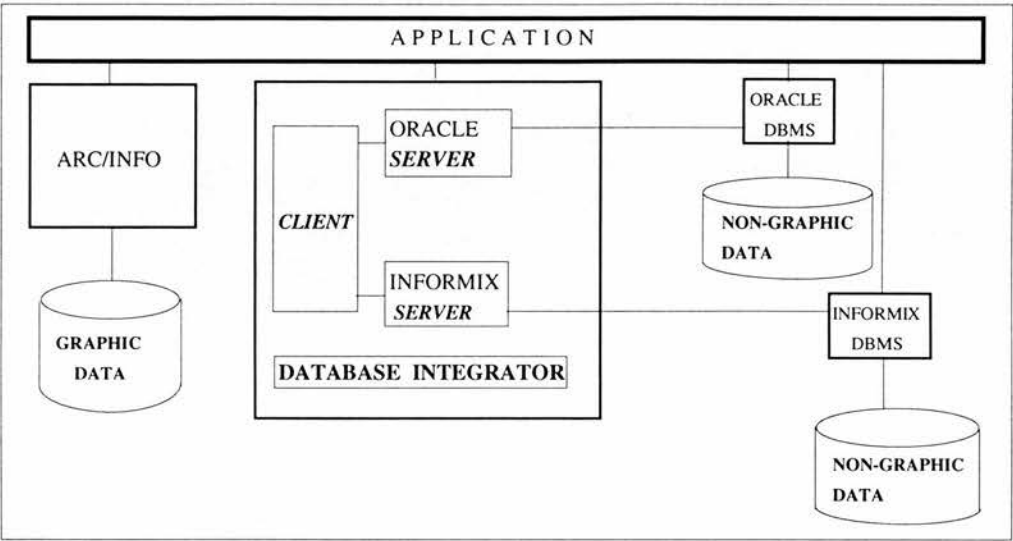


Figure 5.8 The client/server architecture model of database integrator.

Data integrator is the generic term for the family of ARC/INFO software interface modules. The family of database integrator modules provides a standard interface to numerous DBMSs. For example, from ARC/INFO, user can simultaneously access and update data stored in both the INFORMIX and ORACLE DBMSs. The data integrator software is implemented within a client/server architecture model while the core ARC/INFO software consists of a client module which can communicate to many DBMS systems via the appropriate DBMS server, Figure 5.8.

5.10.1 Connecting to the external DBMS from ARC/INFO

The database integrator of ARC/INFO uses a CONNECT statement to log into and establish a connection between ARC/INFO and an external DBMS. The following example shows how to link the ARC/INFO to an ORACLE database using the CONNECT command.


```
Usage: CONNECT <DATABASE> {CONNECT_INFO}
ARC:  CONNECT ORACLE DC APPLE
```

It is noted that each ARC/INFO session may have up to five simultaneous database connections. Each connection creates its own process that maintains the communication path between ARC/INFO and the external DBMS.

5.10.2 The relate environment

Additional attribute tables can be temporarily associated with a coverage's feature attribute table by an operation known as a 'relate'. A relate is an implementation of ARC/INFO that establishes the linkage between an item in any INFO data file and another item in a named INFO data file or a column in an external DBMS table. Therefore, the relate environment makes use of all the advantages of a relational database structure. If each INFO record has only one related row in the DBMS table, this is known as a 'one-to-one' relationship. When each INFO record has more than one related row in the DBMS table, this is known as 'one-to-many' relationship (ESRI, 1991a). Generally, ARC/INFO (version 6.1.1) is capable of supporting more than one level relates in the external DBMS termed as 'stacked relates' which enhance the capability of database access from the GIS.

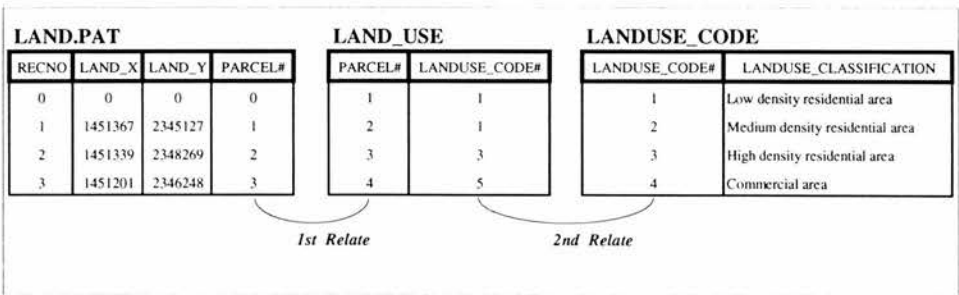


Figure 5.9 Three database tables are related by means of 'stacked relates'.

Stacked relates can access data related to an INFO item across two INFO files or to two database tables contained in the same or separate DBMS systems. Figure 5.9

illustrates a general concept of how three tables are related. LAND_USE and LANDUSE_CODE are both stored in ORACLE. LAND.PAT is in INFO and contains key items which relate it to both LAND_USE and LANDUSE_CODE.

Data in LANDUSE_CODE can be accessed for selected polygons in a LAND coverage by setting up two relates. The first relates the current edit coverage LAND to the ORACLE table LAND_USE by PARCEL#; the second relates LANDUSE_CODE by the key item LANDUSE_CODE#.

ARCEDIT: RELATE LIST

RELATE Name: ONE

Table: LAND_USE

Database: ORACLE

Item: PARCEL#

Column: PARCEL#

RELATE Type: FIRST

RELATE Access: RW

RELATE Name: TWO

Table: LANDUSE_CODE

Database: ORACLE

Item: LANDUSE_CODE#

Column: LANDUSE_CODE#

RELATE Type: ORDERED

RELATE Access: RW

Data in LAND_USE is accessed using the first relate name (ONE) while data in LANDUSE_CODE is accessed by using the first (ONE) and second relate names (TWO).

In summary, the rationale behind the database integrator is that users of LIS/GIS should be able to choose a specific database management system between leading

DBMSs. The choice of a specific DBMS can be decided on the basis of cost, functionality, current database investments and related factors, and need not be restricted by the LIS/GIS software. Therefore, in this research, the ORACLE DBMS (version 6.2) has been chosen to be an external hybrid DBMS software for the proposed Model for Urban Land Readjustment (MULAR) system.

Chapter 6

AN INTERACTIVE AML SYSTEM FOR URBAN LAND READJUSTMENT

6.1 INTRODUCTION

In spite of the tremendous increase in hardware and software in LIS/GIS technology, there are still many limitations to the utilisation of LIS/GIS in the urban planning environment which restrict its effective application. Many users point out that LIS/GIS systems are not advanced enough for established urban policy-making because of the limited capabilities for analysis built into them. Moreover, the systems are not likely to be user-friendly. Therefore, there is a need to develop easy-to-use interfaces with existing LIS/GIS packages.

It is the aim of this chapter to examine the need for and to describe an interactive graphics user interface for urban land readjustment. The interface has been designed for the urban planning environment, and concentrates on making use of the Arc Macro Language (AML) in order to facilitate access for planners to urban land readjustment outlines. The interface has been designed to provide flexibility in data selection, editing, and display; and to allow city planners and decision makers to view and analyse the planning schemes interactively before final decisions are made. This chapter will also examine the use of the interactive layout of the master concept plan as regards the provision of rudimentary public utilities in two different areas in Bangkok, Klong Toei and Lad Krabang districts, for which data were collected. These two case studies involve such complexity of planning details that, even though the areas are small, only sub-areas (STUDY AREAS) are considered in depth in the treatment in latter sections. Treatment in depth is necessary to explore the full potential of the MULAR and AML system.

6.2 DEVELOPING INTERACTIVE SYSTEM REQUIREMENTS

Urban land readjustment is concerned with a wide range of applications and is characterised by the integration of different policy sectors within a spatial framework. Effective urban land readjustment can be fulfilled only if enough information is provided. Consequently, the value of LIS/GIS lies in its potential in reducing the duplications and uncertainties involved in the present decision-making process by yielding accurate, extensive and timely information to be utilised in this process.

The utilisation of LIS/GIS in the urban planning environment is now increasing in demand, but there is as yet little knowledge of computer automation and techniques amongst policy decision makers and city planners. It is hoped that development of intelligent user interfaces will make LIS/GIS systems responsive to user needs while the user will no longer have to gain experience in the use of LIS/GIS except in their own field of expertise.

Greater spending on computer research in the past decade in many leading countries is expected to lead to a large increase in the capabilities of LIS/GIS. A substantial technological aspect of these developments in LIS/GIS is the advent of interactive graphics platforms such as workstations, typically in a network computing environment. The display and interactive capabilities of the workstations provide the basis for an effective dialogue between planners and their spatial problems while the computing power available makes possible the provision of modelling procedures as elements in that dialogue. The computer generated cartographic displays and database management represent very significant potential within the overall decision support system. Using an interactive framework, city planners should be able to see a cartographic representation of the consequences of different planning scenarios.

6.2.1 Determining user requirement

Generally speaking, most discussion of LIS/GIS implementation begins with the customers' requirements. Requirements are commonly developed by documenting the different ways in which the organisation currently handles spatial information, termed 'user needs analysis' of the existing system, and the anticipated future needs. This is done using interviews, analysing the information products and services handled by the organisation, and the systems and procedures used to provide them (Aronoff, 1989). For this thesis, several city planners in the BMA, DTCP, and NHA have been interviewed in the context of how the LIS/GIS technology can help meet the requirements of city planners in the urban land readjustment process (see chapter 3, section 3.6.1). In order to determine and illustrate directly how LIS/GIS can play a role in this new culture, two studies were conducted within the Bangkok Metropolis: Klong Toei and Lad Krabang districts.

6.2.2 Designing the MULAR system

The model for urban land readjustment (MULAR) system, which has already been introduced in chapter 3), is designed as a 'top-down' structure or so-called 'pulldown menu' and it can be shown either in graphics or workstation platform, as depicted in Plate 6.1 and Plate 6.2, respectively. The pulldown menu consists of a main menu bar that displays a list of choices representing the options the menu can perform. Selecting one of the main choices can result in the execution of an operation or the display of a submenu of additional choices that are seemingly 'pulled down' from the menu bar. The MULAR system, Plate 6.3, is divided into six main menu bars: EDITING, ANALYSIS, QUERY, DISPLAY, PRINTOUT, and HELP. The system allows any user to utilise the system to create, analyse, and retrieve data for their own purposes from the coverages available within the system. Selection between menu bars is performed either by clicking a 'mouse' or toggling 'cursor movement keys' and 'enter key'.



Plate 6.1 A graphics terminal, Tektronix 4207.



Plate 6.2 A workstation, DEC VAXstation 3100 M76



Plate 6.3 The six main menu bars in the MULAR system.

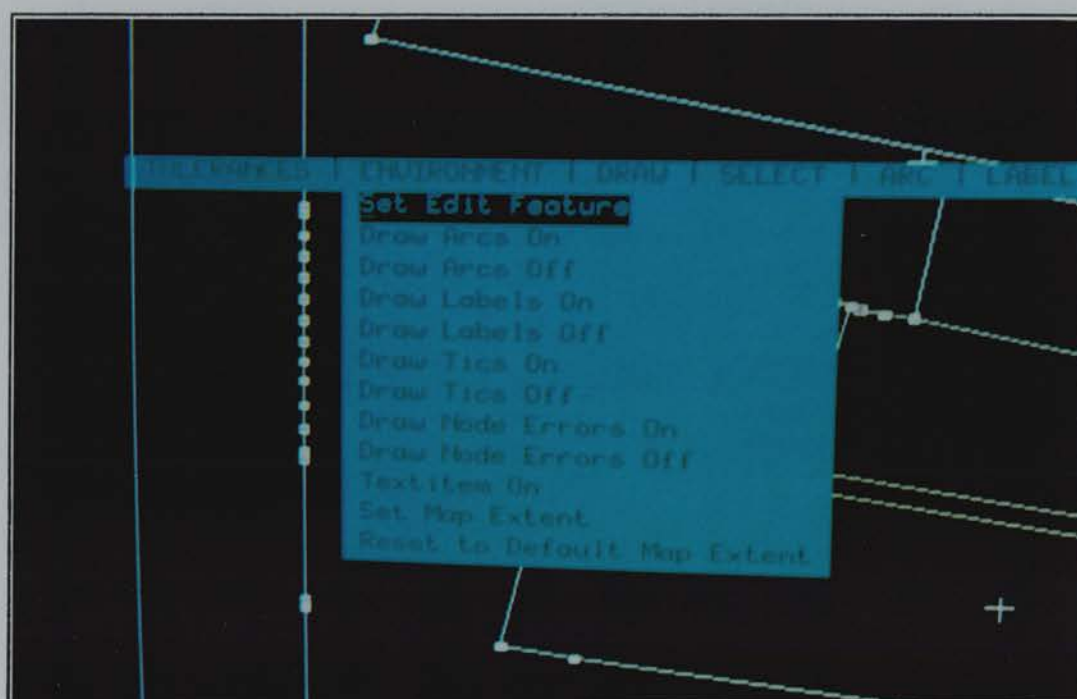


Plate 6.4 The submenu choices in 'editing' capabilities.

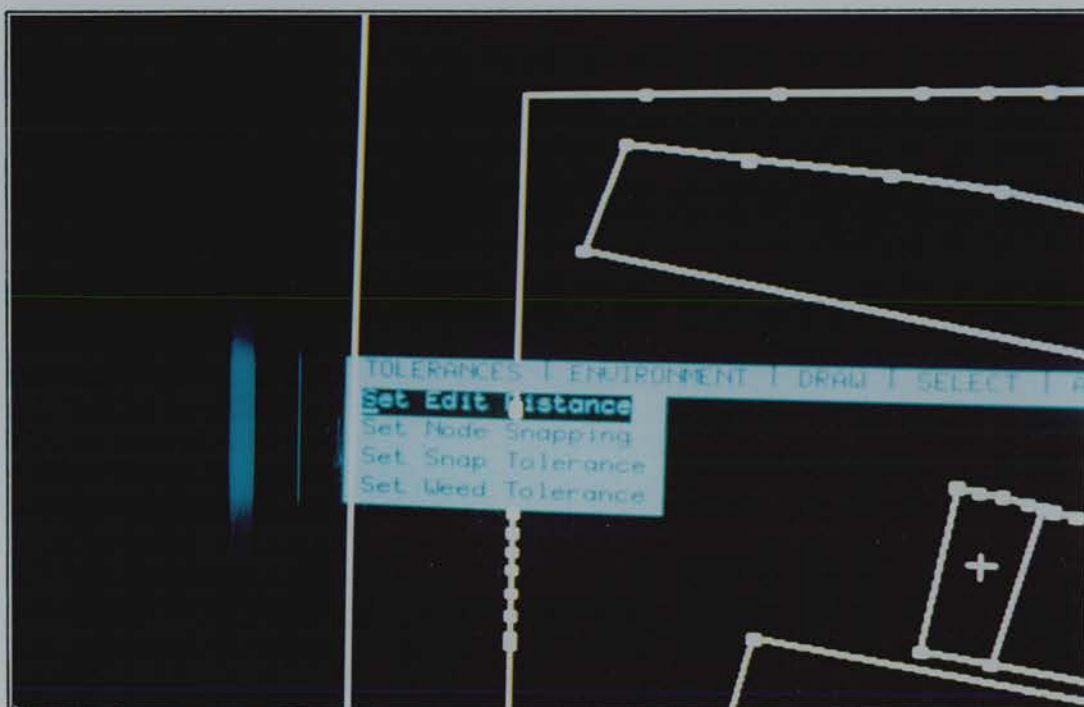


Plate 6.5 The submenu choices in 'TOLERANCES' option.

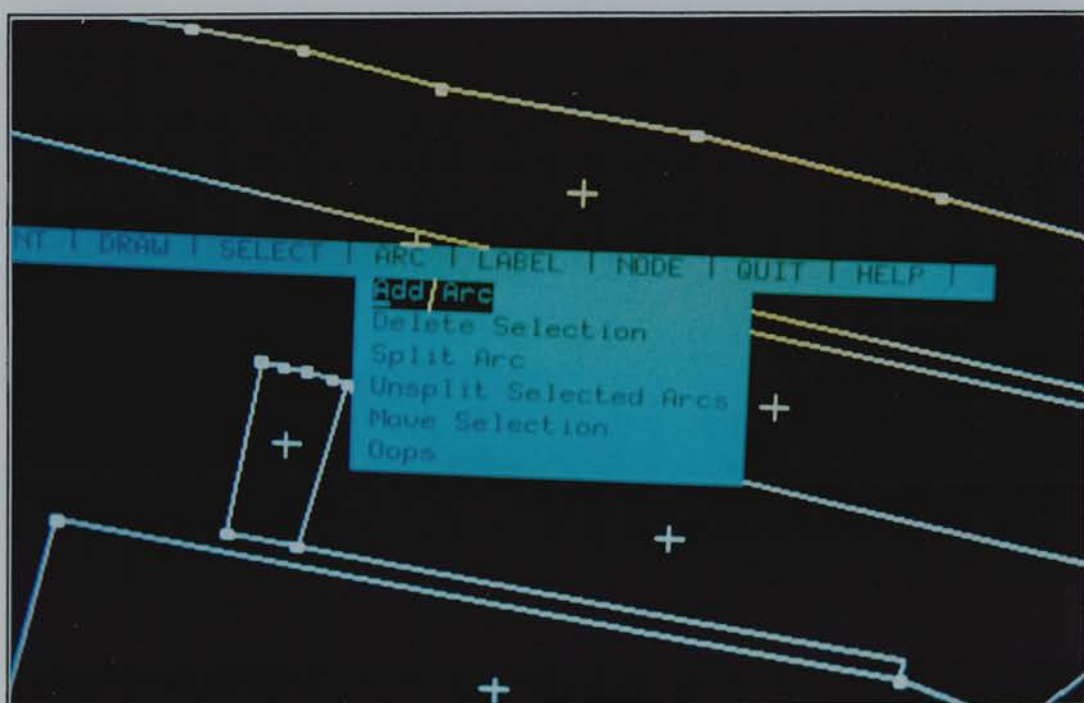


Plate 6.6 An 'Add Arc' option in 'ARC' submenu.

In summary, the top-down structure allows the user to reduce complex problems to clearly defined entities that form parts of a logical structure in a hierarchy.

EDITING

In general, digital cartographic data, which were produced using either a stereoscopic plotter or a digitiser, can be corrected as necessary in respect of lines/arcs, polygons, and points. The EDITING menu has been developed in the ARCEDIT environment where the identified errors, namely missing arcs, more than one label point in a polygon, a gap between two arcs or an unclosed polygon, can be corrected. For example, adding an additional arc in a polygon coverage can be executed by the following steps:

- Select 'Set Edit Feature' in the Environment option (see Plate 6.4).
- Select 'Set Map Extent' in the Environment option.
- Bring the screen cursor to locate the selected area where the additional arc will be added.
- Set 'Edit Distance', 'Set Node Snapping', 'Set Snap Tolerance' in the Tolerance option (see Plate 6.5).
- Select 'Add Arc' in the Arc submenu (see Plate 6.6) to add new arc to the current polygon coverage and select 'Quit' to exit the prompt key menu.
- Select 'Save' to save or choose 'Save & Quit' to save the added arc and exit from the editing environment to the main MULAR system.

ANALYSIS

After digitising, a feature attribute table (eg .PAT for polygons and points, .AAT for arcs) is created by the BUILD or CLEAN command. The analysis module is also composed of analysis functions, namely overlay and buffer processes. The analysis menu has been developed to perform in an interactive mode between the computer and the user. The AML has been written in the ARCPLOT environment to help the city planners to select particular lines/points for buffering according to the designated distances or for shading certain polygons for land use classification purpose. Plate 6.7

illustrates the capability of the ANALYSIS menu to select particular polygons (indicated by small square symbols). The computer will display a 'Enter the shade symbol' prompt for the user to type the required shading symbol.

QUERY

In this menu, non-graphic/attribute data loaded in the ORACLE environment can be connected and retrieved by means of the written AML programs which are embedded in the MULAR system. For example, querying the land value of the 'study area 1' in the Klong Toei project in 1992 can be achieved by clicking on the pulldown submenu in the main QUERY menu bar. The AML will provide a 'cursor'; with the cursor, data can be displayed and retrieved from the RDBMS table. Therefore, the user has access to the data without needing to know ARC/INFO commands.

DISPLAY

The DISPLAY menu provides a set of codes that will be used in the ARCPLOT session. Once a code of the graphics or workstation terminal (eg 4207, 9999) is specified in the DISPLAY option, the screen will clear as the device is put into screen graphics mode. On graphics terminals, the ARCPLOT will appear at the bottom of the screen in the common dialogue area. On workstation terminals, the ARCPLOT prompt will show in a separate window. In addition when 1040 code is chosen in the DISPLAY option, the user will be prompted for the plot file name. This plot file can be submitted via the PRINTOUT menu to produce hard copy maps.

PRINTOUT

The PRINTOUT menu is the final stage of the MULAR system where the plot files created in the DISPLAY menu can be selected and sent to the desired destination. Plate 6.8 shows the possibility of sending the plot files in either vector (HP 7550) or raster (POSTSCRIPT) format to produce maps of various forms in the required plotter or laser printer.

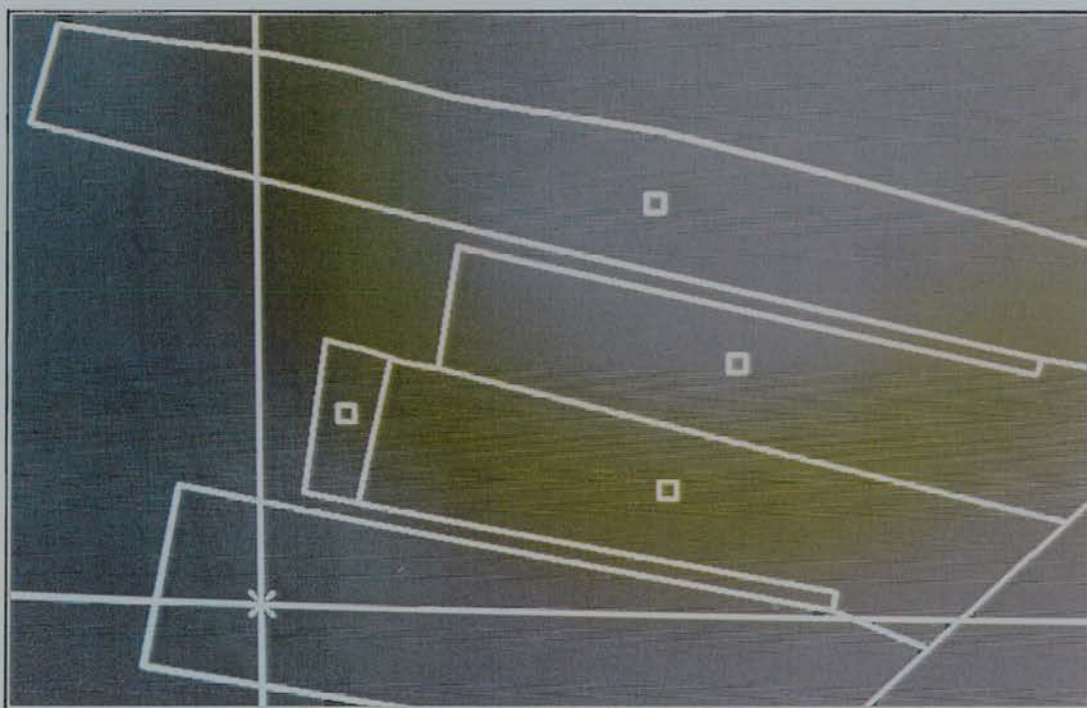


Plate 6.7 A graphic capability to analyse in the MULAR system.

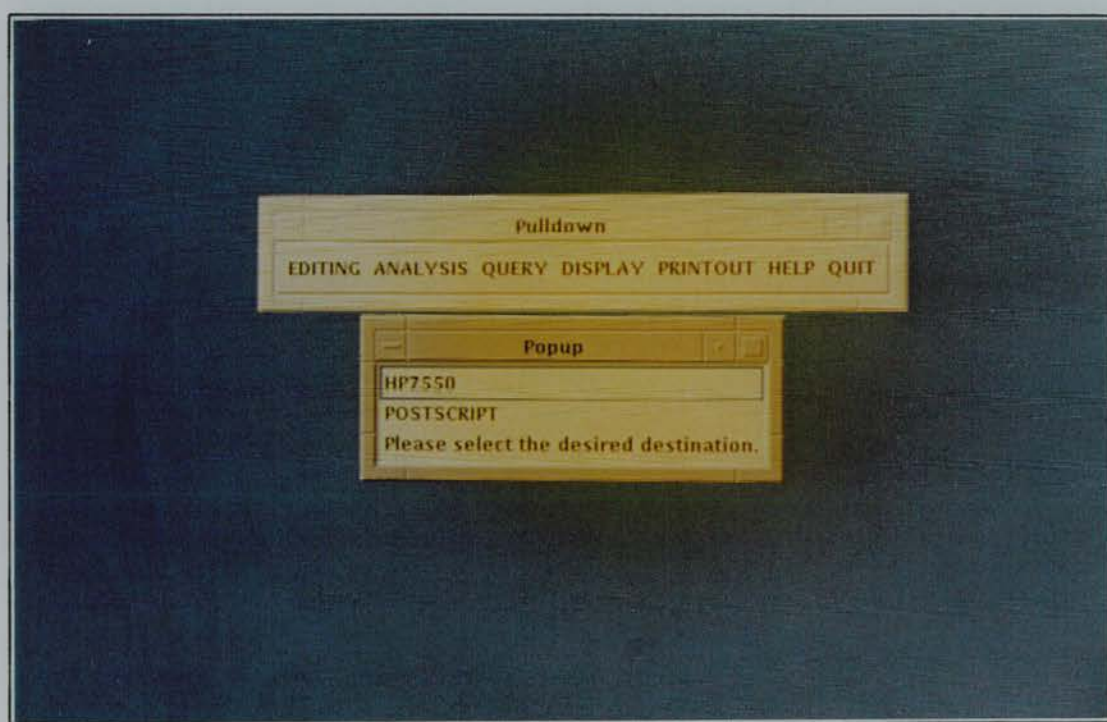


Plate 6.8 The 'PRINTOUT' options in the MULAR system.

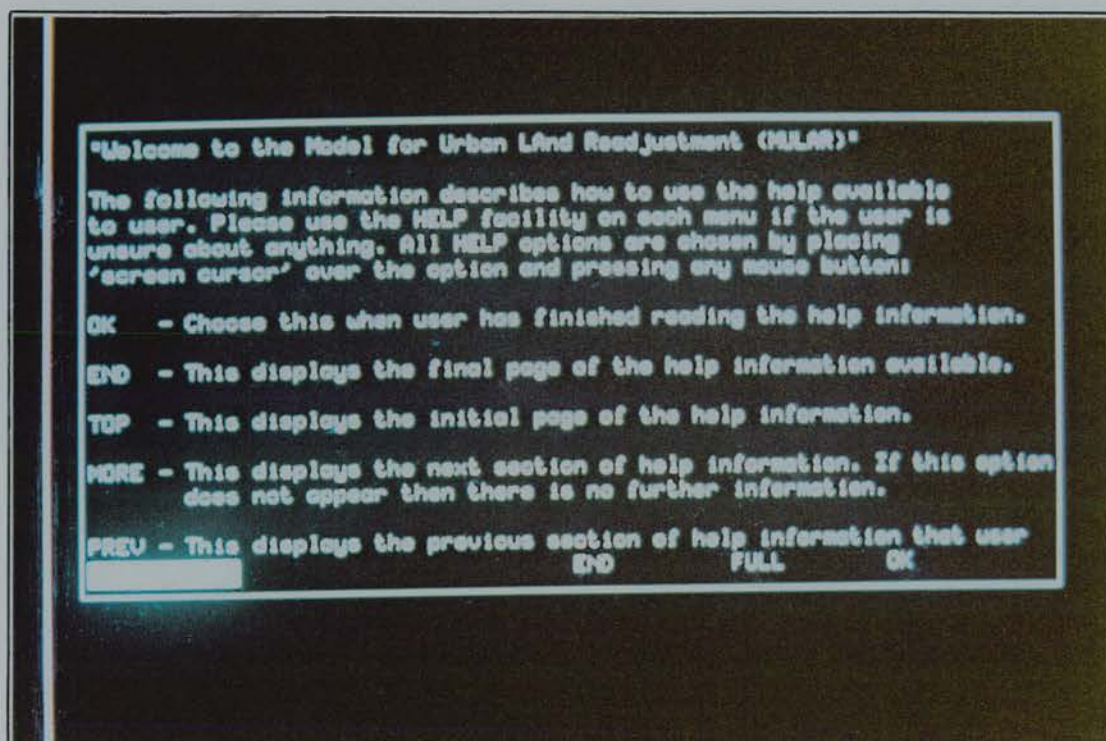


Plate 6.9 A 'HELP' option in a submenu choice in the MULAR environment.

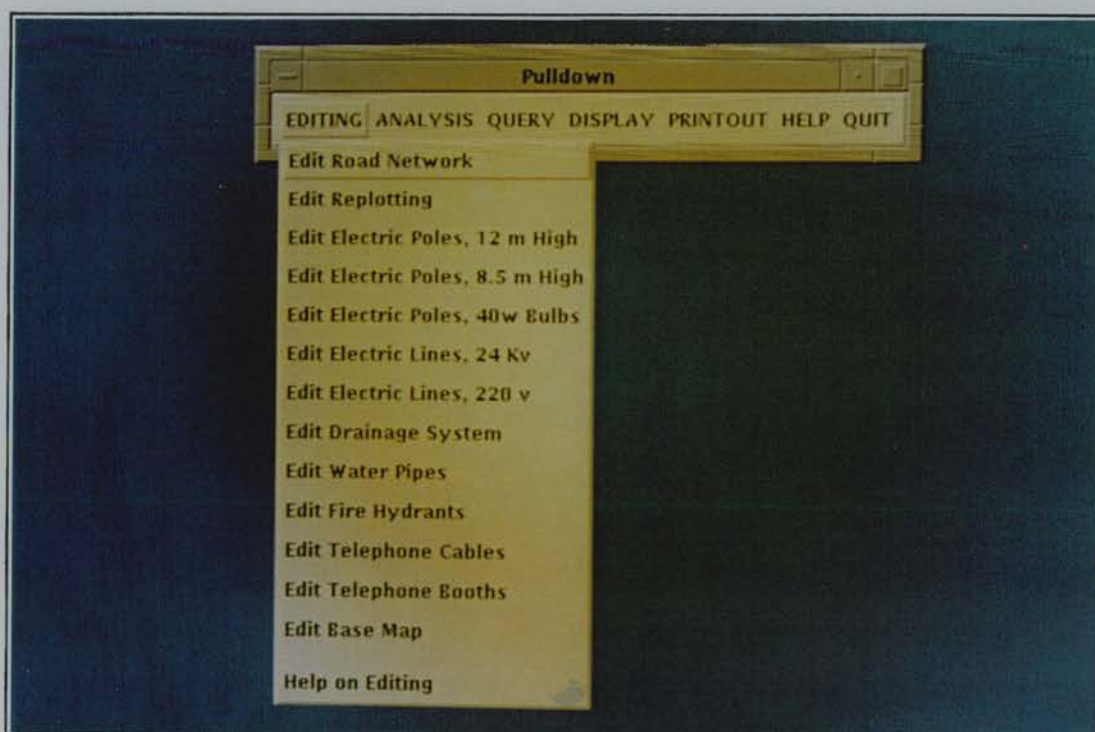


Plate 6.10 A set of submenu bars for 'EDITING' in the MULAR system.

HELP

The HELP menu has been developed to display on-line documentation (as a so-called 'help screen'). It includes informative materials, directions for using services, instructions for filing claims, and other explanatory text designed to meet users' needs. Plate 6.9 depicts the display of scrollable text file in the popup window on the graphic terminal. The following scrolling options appear on the terminal if the information being displayed is longer than the window. These options permit paging through the window and are displayed on the last line of the window.

OK - terminates the popup display.

END - moves to the end of the popup window.

TOP - moves to the top of the popup window.

MORE - scrolls the window forward.

PREV - scrolls the window backward.

Therefore, care is taken to ensure that the text is written within the defined window size parameters to avoid the text being truncated and lost from view. All help screen are stored as text files, created with the VAX editor, in directories [DC.ARC.KLONG] and [DC.ARC.LAD].

QUIT

Whenever QUIT is invoked in the main menu bar, the AML command will stop execution of the ARC system and return control to the VAX environment.

6.2.3 Developing the menu interface with AML

The MULAR system is designed to achieve the rudimentary principles of a user-friendly system, that is, that it should satisfy human, physical and psychological requirements (Silver and Silver, 1989). With this in mind, MULAR has been designed to be simple, comfortable and meet city planners' needs. Development of the user interface was undertaken using the 'menu interface' facilities available within AML. AML menus are ASCII text files created with any text editor;

nonetheless, AML menus are not AML programs. They differ in how they are named, formatted and executed. AML provides a tool called 'cursor' which can access data stored in external databases, such as ORACLE, as well as being able to access INFO. In addition, the AML is a programming language that provides full programming capabilities and can be used throughout the ARC system to perform a variety of task (ESRI, 1992). The naming convention for menu files is a descriptive file name followed by .MENU extension. The AML menu is invoked with the &MENU directive which executes a menu file and invokes the graphical user interface (GUI). As an illustrative example, the menu file CHOICE1.MENU in the directory [DC.ARC.KLONG] is written to display information of an urban land readjustment project in the Klong Toei district.

In the menu interface, all main menu bar and submenu options are displayed on screen in a well-designed, visually appealing environment which is particularly suited to the less experienced ARC/INFO users. All the menu options should be displayed on the screen so that choices can be made with the help of mouse and cursor movement keys. The menu interface provides query capabilities, displaying only valid choices, and users can place a series of ARC/INFO commands that accomplish a single task in an AML program and execute it from a menu. This can reduce the amount of typing errors and helps keep users from being confused by too many options. In addition, it permits input data to be verified before proceeding to the next process.

Menus are typically a listing of set of choices. With AML facilities, user can create seven types of menus, namely pulldown, sidebar, matrix, key, tablet, digitiser, and form menu. Menu types differ in how they look, where they appear on the screen and how the user interacts with them. The pulldown, sidebar and matrix menus are displayed on the screen in various positions, and the user makes a selection by pointing to a choice and clicking the mouse. Key menus appear in the dialogue area or window where commands are typed while tablet and digitiser menus are paper

menus placed on a tablet or digitising board. Form menus enable the user to make choices, as in pulldown and sidebar menu, but they also accept input from the keyboard and can incorporate scrolling list within the menus themselves (ESRI, 1993). In designing a menu interface for urban land readjustment in Thailand, a pulldown menu type and command line options were chosen, together with the use of SQL for query RDBMS purposes. The main MULAR menu bar remains on the screen while the submenu is present. The submenu remains on the screen only until a choice is made. The file that generates this submenu (Plate 6.10) is listed below.

```
[1] 1 CHOICE1 MENU
[2]
[3] EDITING
[4] 'Edit Road Network' &R EDITING1 COPLR1
[5] 'Edit Replotting' &R EDITING2 REPLOT
[6] 'Edit Electric Poles, 12 m High' &R EDITING3
[7] 'Edit Electric Poles, 8.5 m High' &R EDITING4
[8] 'Edit Electric Poles, 40w Bulbs, &R EDITING5
[9] 'Edit Electric Lines, 24 Kv' &R EDITING6
[10] 'Edit Electric Lines, 220 v' &R EDITING7
[11] 'Edit Drainage System' &R EDITING8
[12] 'Edit Water Pipes' &R EDITING9
[13] 'Edit Fire Hydrants' &R EDITING10
[14] 'Edit Telephone Cables' &R EDITING11
[15] 'Edit Telephone Booths' &R EDITING12
[16] 'Edit Proposed Buildings' &R EDITING13
[17] ' '
[18] 'Help on Editing' &POPUP [DC.ARC.KLONG]EDITING.HLP 20 75 0 0
[19] QUIT &RETURN
```

The number on line [1] indicates the menu type (pulldown). Text appearing on the first line after the type is read as a comment. The second line is read as a comment during execution. The third line creates a main menu bar called 'EDITING'. The submenu for the EDITING is created by lines [4] through [16]. Whenever a choice contains two or more words, the choice must be quoted (eg 'Edit Road Network'). Each line in a menu file define two operations: the 'action' that is executed when a choice is selected (eg &R EDITING1) and the 'choice' that is graphically displayed to the user (eg displaying coverage named COPLR1). A blank space between choices on the screen in the submenu can be made by including a quoted blank space (' ') on the line (17) in the menu file. A 'help screen' can be interpreted by line (18) while exit to the main menu bar can be executed in line (19). The maximum number of displayed choices that can be defined in the menu file is 150. The main menu bar is limited to 20 choices; each choice is limited to 32 characters (eg 'Help on Editing' is 15 characters).

In summary, a menu interface is composed of two parts; a menu file and the graphical user interface that is shown on the screen. Menu files are ASCII text files including menu choices and their subsequent actions. Menus graphically display the choices to the user. The MULAR system is designed by means of a pulldown menu which is invoked using the &MENU directive.

6.2.4 Creating AML programs

The design of the interactive MULAR system is built upon the following two principles:

1. The system should provide a fully interactive graphic interface so that the spatial and aspatial dimensions of data can be clearly seen.
2. The system should have an automatic linkage between graphic data embedded in the system and the non-graphic data loaded in a RDBMS package.

The application of the interactive MULAR system, involving AML programs, has been applied to two study areas in the urban and suburban environment in Bangkok. The rationale design of the system for the areas is quite similar in definition and function to the 'choice menu' except that in the suburban area users have more choices for urban facility analysis than in the urban area. An extensive set of AML functions and directives has been used in both projects. The Klong Toei project is chosen as an example of the application of the MULAR system.

The main program is called START1.AML (Appendix 6.1). When executed the START1.AML calls the main menu (CHOICE1.MENU) which lists a set of main menu bars (see Plate 6.3 and Appendix 6.2). There are five major types of programs developed in the MULAR system as follows:

1) Editing capability

A EDITING1.AML file allows a target coverage to be fully interactive and a 'modular programming' technique is undertaken. Because modular programming creates many smaller programs instead of one large one, modular programs need to call other programs and menus, Figure 6.1. With AML, users can, for example, create a macro to set up the appropriate editing environment in ARCEDIT as shown below.

```
&ARGS COVNAME
```

```
ARCEDIT
```

```
&SV DEVICE = [GETCHOICE 4207 9999 'Please enter a graphic device''s code.]
```

```
DISPLAY %DEVICE%
```

```
MAPEXTENT %COVNAME%
```

```
EDITCOVERAGE %COVNAME%
```

```
&IF [EXISTS %COVNAME% -ARC] &THEN
```

```
&SV TEMP = ARC
```

```
&IF [EXISTS %COVNAME% -POINT] &THEN
```

```
&SV TEMP = %TEMP% LABEL
```

```

&IF [EXISTS %COVNAME% -POLY] &THEN
&SV TEMP = ARC LABEL
DRAWENV ALL %TEMP%
DRAW
&MENU EDIT1
&RETURN

```

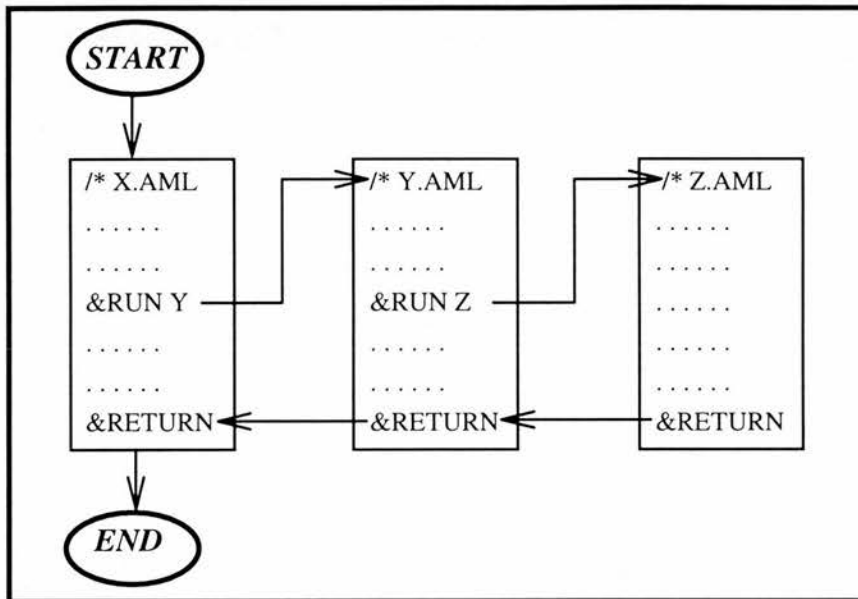


Figure 6.1 A 'modular programming' in the MULAR system.

The &SV directive creates or sets the value of the AML variables related to the given function (GETCHOICE) which displays a menu of a list of choices (eg 4207, 9999) from which a selection can be made. The target coverage, which can be line, point or polygon, is retrieved and displayed according to variable name (COVNAME) from the &ARGS directive. Following this, the &MENU directive invokes the EDIT1.MENU program (Appendix 6.3). In this case, the EDIT1.MENU file is called for editing operation. To terminate the interactive operation and continue executing the other main menu bar, SAVE & QUIT is selected. With the help of &RETURN directive written in the EDIT1.MENU file, the file is terminated and control returns to the main MULAR menu.

2) Background display and editing capability

A EDITING6.AML file permits a designated coverage to be used as a background display while a target coverage is being edited. In designing new locations for proposed urban utilities in the Klong Toei project, several commands in ARC/ARCEDIT are selected to enhance the editing capability in the EDITING environment. Using this program, users can easily design a new graphic model without disturbing a designated coverage used as a background. A part of the file is shown below, while the complete program is presented in Appendix 6.4.

```
&SV COV1 = E24KV
&SV MASTER = COPLR11
CREATE %COV1% %MASTER%
ARCEDIT
&SV DEVICE = [GETCHOICE 4207 9999 'Please select a graphic device '' code']
DISPLAY %DEVICE%
BACKCOV %MASTER% 2
BACKENV ARC
MAPEXTENT %COV1%
EDITCOVERAGE %COV1%
DRAWENV ARC
DRAW
&MENU EDIT1
&RETURN
```

3) Analysis capability

Manual techniques of map analysis are both tedious and analytically limiting. For the last two decades digital mapping systems have been used in production environment by the mapping community with different degrees of success (Ramirez, 1991). Digital data are now often acquired in order to provide for more efficient planning (Stefanovic *et al.*, 1980). LIS/GIS have recently been given a great deal of attention

primarily because of the realisation that the technology contributes a vast potential (Pong-chai Goh, 1989) which, if properly used by city planners can provide solutions to many land resource management problems. The LIS/GIS are deemed to provide valuable new information, rather than monitoring old tasks more efficiently. Therefore, the MULAR system has been developed to perform geographic and graphic analysis, namely buffering polygons/lines/points, and shading designated polygons. With the help of AML, spatial analysis can be fully interactive between computer and users by typing in a prompt command line. A part of the AML file (ANALY13.AML) is referred to as follows:

```

MAPEX %COVNAME%
POLYS %COVNAME%
&SV FILEUNIT [OPEN TEMP.DAT OPENSTATUS -WRITE]
&IF %OPENSTATUS% NE 0 &THEN
&RETURN ERROR - File TEMP.DAT could not be opened.
&SV STOP = .TRUE.
&DO &UNTIL %STOP% = .FALSE.
&TYPE Select a polygon to shade using the cursor.
RESELECT %COVNAME% POLYS ONE *
&SV ID [SHOW SELECT %COVNAME% POLY 1 ITEM [ENTRYNAME ~
%COVNAME%]-ID]
&SV SYMBOL [RESPONSE 'Enter the shade symbol']
&SV RECORD %ID%, %SYMBOL%
&SV STAT [WRITE %FILEUNIT% %RECORD%]
&IF %STAT% = 0 &THEN
&TYPE %RECORD% written to TEMP.DAT
&ELSE
&SV STAT [CLOSE %FILEUNIT%]
&IF %STAT% NE 0 &THEN
&TYPE WARNING - File TEMP.DAT not closed properly.

```



```

QUIT
&IF [EXISTS %COVNAME%.LUT -INFO] &THEN
&SV ALREADY YES
&ELSE
&SV ALREADY NO
&DATA ARC INFO
ARC
&IF %ALREADY% = YES &THEN
&DO
SELECT LUSE94.LUT
&END
DEFINE LUSE94.LUT
LUSE94-ID, 2, 2, I
SYMBOL, 2, 2, I
~
ADD FROM [-]TEMP.DAT
SORT ON LUSE94-ID
Q STOP
&END
~DELETE TEMP.DAT;*
JOINITEM %COVNAME%.PAT LUSE94.LUT %COVNAME%.PAT ~
LUSE94-ID LUSE94-ID
&DATA ARC INFO
ARC
SELECT LUSE94.LUT
ERASE LUSE94.LUT
Y
Q STOP
&END

```

The main purpose of this program is to display a target coverage and allow users to select the polygon to be shaded by introducing the 'movement keys', 'space bar' and 'return' key. A prompt command line will be successively shown, permitting users to type the number of shade symbol (eg 'Enter the shade symbol': **32**). At this stage, the polygon-ID and shade symbol code will be recorded in a temporary file called TEMP.DAT. Following this, the users have to respond to a prompt command line, 'Select another polygon? (Y or N)', which is displayed on the screen by typing 'Y' or 'N'. Introducing 'Y' results in redrawing the coverage and selecting a new polygon, while introducing 'N' results in terminating the polygon selection process. A lookup table file, LUSE94.LUT, will be created in INFO environment where the TEMP.DAT will be automatically joined afterwards. After joining is completed, the TEMP.DAT file will be deleted and the 'join item process' of a common feature-ID between .PAT and .LUT of the coverage is continued. As soon as 'join item process' is complete, the lookup table file will be deleted so as to minimise the memory space. The target coverage is subsequently used in the DISPLAY environment.

4) External linkage with RDBMS package

This allows a linkage between graphic data in the ARC/INFO environment and attribute data in the ORACLE package to be connected and related to each other using a common feature-ID. A QLV92.AML file, as shown in Appendix 6.5, illustrates the scope of the MULAR system to connect, relate and retrieve the land-related data loaded in the RDBMS environment according to a set of conditions specified. For example, the condition could be set of land assessed in 1992 for taxation at a land value of 35000 Baht/sq wah, and then a polygon or set of polygons can be selected and shaded in the ARCPLOT environment.

5) Displaying facility

In general, viewing of two-dimensional graphic output in DISPLAY menu is regularly generated in ARCPLOT environment. With the help of a Triangulated

Irregular Network (TIN) package, a geographic surface model can also be created, analysed, and displayed in perspective and panoramic views. For example, a DMIN3D.AML file, Appendix 6.6, in CHOICE2.MENU in the [DC.ARC.LAD] directory is invoked to display a three dimensional viewing of the Lad Krabang project (Figure 6.2) where a total of 2540 sample points, regularly spaced at 20 m intervals and generated as X, Y, Z coordinates from the AP190 analytical stereoplotter, are converted to a lattice surface coverage called 'FLAT1'. A vertical exaggeration factor of 100 is applied to the surface viewing environment. The area on the graphics page (eg SURFACELIMITS) where surface views will be drawn and the interpolateable region (eg SURFACEEXTENT) of the current surface are also defined. A pair of X, Y coordinates of the viewing target in metre units is specified (eg SURFACETARGET 686700, 1522500) for the generation of surface views and viewshed analysis. The point of observation is given by specifying the relationship between the viewing target and the point of observation. The point of observation is specified in terms of the horizontal angle (225°), vertical angle (35°), and horizontal distance in the ground units (1000) relative to the viewing target. The field of view angles are automatically adjusted/recalculated to view as much of the surface as possible without causing excessive distortion (ESRI, 1991b). In addition, SURFACEDRAPE commands in the ARCPLOT are used to create surfaces of various views by draping a network of lines, graphics files, and point coverages. For instance, the commands drape lines parallel to both the X- and Y-axes of the current surface (or so-called 'FISHNET') with the distance of 10 metres between mesh line.

In conclusion a modular programming technique not only makes the program less complex and easier to understand than one, long program but also makes maintaining application easier. With the help of ARC/INFO facilities, it is possible to design the proposed location of urban facilities and urban utilities using a 'cadastral' coverage as a background.

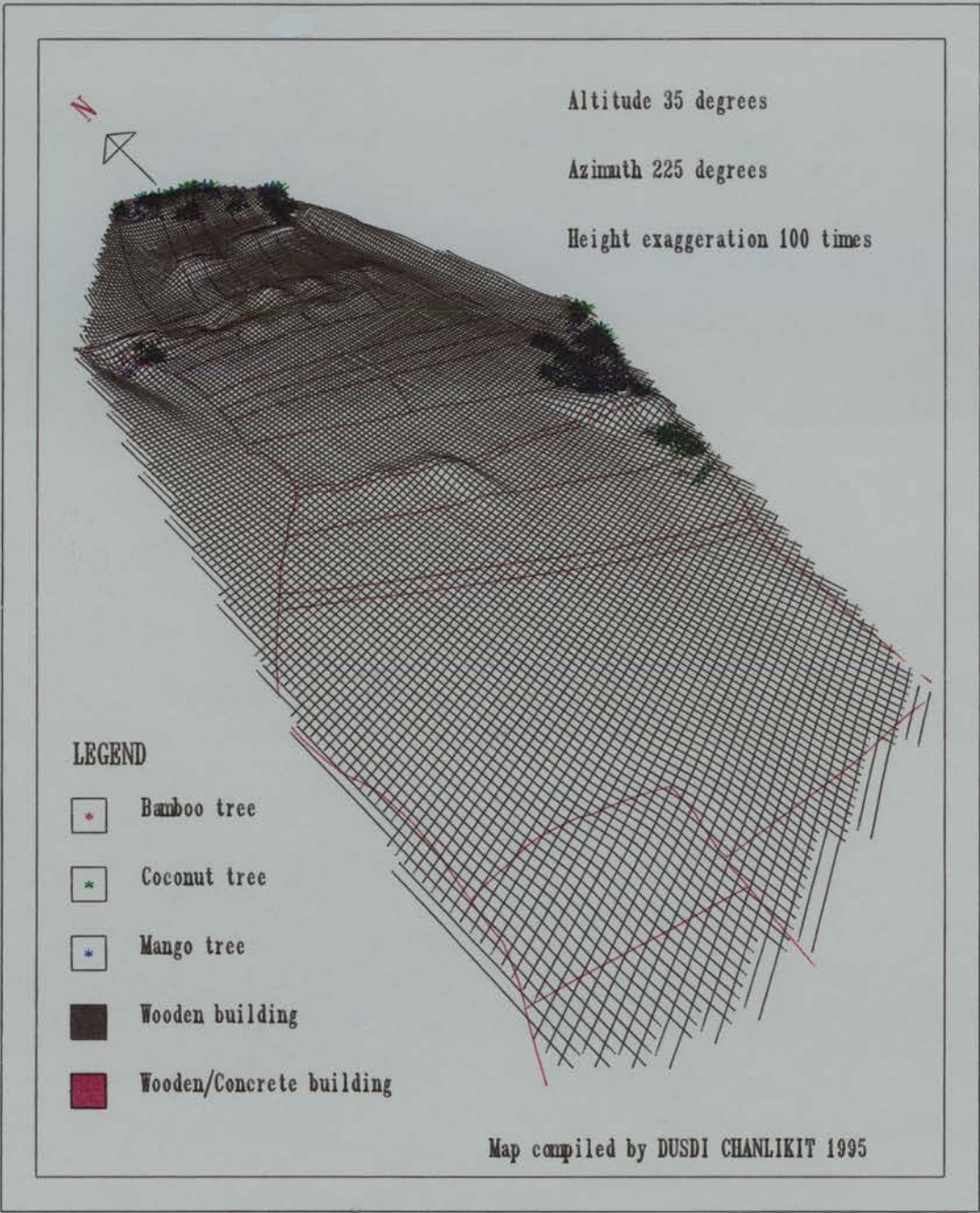


Figure 6.2 A three dimensional viewing in the Lad Krabang project.

In addition spatial analysis can be repeated in a fully interactive operation in the ARC/INFO/ARC PLOT environment, while there is also an interactive ARC PLOT RESELECT for more expert users to select the area of interest for a special urban land information system according to their own criteria. The utilisation of the 'help screen' allows the integration of graphics and text because the help screen does not erase the graphics screen when it is displayed. These facilities provide greater flexibility and more control over the MULAR system.

6.3 SOLUTIONS TO URBAN LAND READJUSTMENT IN BANGKOK

The significant point to note about urban land readjustment projects is that, if they are properly conducted, the net result is to create new urbanisation at no expense to local government, and at a reasonable profit to the owners involved. The four main keys considered to play a vital role in the success or failure of undertaking the projects are:

- layout of master concept plan;
- cost estimation plan;
- replotting of parcels;
- list of new parcels and valuations.

6.3.1 Layout of master concept plan

A master concept plan is conducted in order to check the details of the area for project implementation when the area has been located and implementation of the land readjustment project is considered possible. A study is then carried out to investigate the current condition of the project area so that the master concept plan can be drawn. The master concept plan results from this study as a guide plan which shows the direction of development and improvement of the project area; it also clarifies the basic policy which is a guiding concept of how and where public

facilities (eg roads, parks) and block design for each land use should be located. The rationale behind the master concept plan is that it should be drawn in conformity with the current Bangkok Metropolis General Plan (Ministerial Regulation No. 116, B.E. 2535). The layout of network of the road has a vital effect on the urban land readjustment procedure as the road network determines the economic, environmental and physical framework for replotting. The road network in the project area has also to be planned to attain systematic, smooth and safe traffic flow while blocks enclosed by the roads should be well designed so that lots being located in each block can be efficiently used in accordance with the land use plan. Each block must also accommodate the existing lots without any large differences in location of lots before and after the execution of the project through techniques of replotting (JICA, 1989).

6.3.2 Cost estimation plan

Urban facilities are planned and designed in accordance with the master concept plan which has now been drawn - all necessary public works are listed and set in priority. Beyond that, plan and design for the implementation of urban land readjustment such as removal and demolition of buildings and other structures like electric poles and waterworks should be prepared.

Cost of the project is estimated including cost of all sorts of construction works which are implemented in the project, shared defrayment of waterworks and sewerage system, compensation for loss and damages, interest on loans during construction, cost for study and design, survey, land title, tree and landscaping, contingencies and others. In the research, cost estimations of construction works are referred to standard prices of various government agencies, for example, the NHA and MEA (NHA, 1992; MEA, 1992).

The cost estimation plan shows the project expenditures which are needed to carry out the implementation programme for the project, and the amount of loan funds that will be required.

6.3.3 Replotting of parcels

In urban land readjustment, land parcels are initially all different in shape and are replotted with a reduction in area as a 'contribution' - the contributed lands are required for public utilities and as cost recovery lands. The 'replotting' plan is also drawn in order to reinstate the landowners as much as possible on or near their original locations. Therefore, replotting is the key to the urban land readjustment project. The most important part of the replotting plan is the 'replotting design'. A Japanese replotting design called the 'proportional formula of replotting' has been exploited for replotting design in both the Klong Toei and Lad Krabang projects. Basically, it means the development benefit is shared proportionally amongst the landowners to arrive at a proposed plotting plan (Buranasiri, 1992).

The replotting design is the process of determining what replotted land - located where and of what area and shape - should be exchanged for pre-project land. The design must correspond with the pre-project land in such factors as location, acreage, soil condition, accessibility to water supply, state of land use and environment - this is called 'the principle of correspondence'. It is also necessary to calculate the average contribution ratio of the project area where replotting is to be designed, and to examine the relationship between the land for public facilities and the land for cost recovery. These procedures are deemed to be a fundamental basis of the replotting design, and intimately related to land evaluation.

In a sense of urban land readjustment, an evaluation of property (land, buildings and trees) plays an important role for the replotting design. The purpose of property evaluation is to estimate the 'market value' of land, buildings and trees based on

knowledge, experience and judgement. Market value is an estimation of the highest price in terms of money which a property will bring if exposed for sale on the open market for a reasonable period of time to find a potential purchaser who buys with knowledge of all the uses to which it is adopted and for which it is capable of being used. The evaluation of property is composed of separate evaluation of land, buildings and trees.

(1) Evaluation of land

As land evaluation is a significant part of the equitable handling of land and its related rights, the objectives of land evaluation are therefore to create a basis for calculating for the replots, to acquire reserved land, and to calculate the compensation for any decrease value. It is vital to evaluate a large amount of land, with consideration of the relationship between lots before and after the development, objectively, fairly, speedily, and systematically, using the same standard. There are accepted methods of land evaluation currently used in the world over, namely, street value, zone price, and market comparison value methods.

- Street value evaluation method

In this method, a land parcel with a standard frontage, depth and shape is hypothesised, and the hypothetical land value per unit area (eg a square metre unit) which is called 'street value' is calculated on the basis of the street parcel faces. This hypothetical land value is modified by such individual characteristics as actual parcel shape and condition, and the relationship with the street it faces in order to get the value of individual parcels (JICA, 1989).

- Zone price method

Where the street value evaluation method seems to be unsuitable because the land is extensively covered by farmland or forest, land can be evaluated by using a 'zone

price', whereby the project site is likely to be divided into zones with approximately the same land price.

- Market comparison value method

The simplest land evaluation method is to make a comparison of the land to be valued with similar lands in the vicinity that have recently been sold. The assumption with this method is that the value of an object is equal to the prices recently paid for the purchase of similar objects. The market comparison value method is the most efficient means of determining open market value but its application requires the availability of an active market, as described by Manneh (1992) for another country. The open market value is defined as the most probable price in terms of money which a property should bring in a competitive and open market under all conditions requisite to a fair sale with the buyer and seller each acting prudently, knowledgeably and assuming the price is not affected by any undue stimulus (NESDB, 1994). It is noted that land value in the study areas has been periodically assessed for taxation using the market comparison method (DOL, 1992) and the data were available for this study from 1976 up until 1992.

(2) Evaluation of buildings

There are two promising methods of building evaluation, namely, bill of quantities and unit comparisons.

- Bill of quantities

Where detailed drawings and a specification are available, it is possible for a bill of quantities to be prepared and for this bill to be priced by a quantity surveyor or contractor (Britton *et al.*, 1989). This method is regarded as providing the most accurate evaluation of building but is rarely practicable. By this method, the total

current value of a building (B) can be evaluated by adding all current prices of building materials (TP), together with current administrative and construction costs (C), and subtracting the building depreciation (D), where depreciation is dependent on the type of building (eg concrete or wooden) and the number of years the building has been in use.

Therefore,
$$B = TP + C - D.$$

- Unit comparisons

The more common but more approximate method is by comparing building costs per square area (eg a square metre) of gross floor area. The gross floor area having been determined, the total cost can be estimated by applying a price per square metre derived from experience of the cost of similar buildings or from a reliable publication. Furthermore, the gross floor area is usually determined by taking the total floor area of all storeys of the building measured outside external walls and without deduction for internal walls (Britton *et al.*, 1989).

Consequently, the total current value of a building (B) in this method can be assessed by multiplying the gross floor area (G) and a current average price of building materials (P), adding current administrative and construction costs (C), and then subtracting depreciation.

Hence,
$$B = (G * P) + C - D.$$

In this research, the gross floor area of the buildings within the study areas was derived by means of stereodigitising from the AP190 stereoscopic plotter and the number of floors was found by field completion. The current average construction cost per square metre (C), including administrative cost and average price of building materials, was quoted from a private firm situated in Bangkok which deals with building assessment. The depreciation of building is set according to the standard of

Ministry of Interior (MOI, 1992), as shown in Table 6.1. Therefore, the equation for evaluation of building in this table is as follows:

$$B = (G * C) - D.$$

Table 6.1 Percentage of building depreciation values.

Period of buildings (year)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Concrete building (%)	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24	26	28	30
Concrete/wooden building (%)	2	4	6	8	10	14	18	22	26	30	34	38	42	46	50	55	60	65	70	75
Wooden building (%)	3	6	9	12	15	20	25	30	35	40	45	50	55	60	65	72	79	86	93	93

Source: The Ministry of Interior (MOI) as at 1992.

(3) Evaluation of trees

The data related to the number and type of trees were collected by air photo interpretation and the trees were later re-checked by field completion. The price of trees is dependent on the compensation price standard set by the MAC where classification is established according to type (eg coconut, mango) and size of tree (small, medium, big), as shown in publication of MAC (1991, Appendix 4.8).

6.3.4 List of new parcels and valuations

Urban land readjustment involves a partnership of landowners in a project. Their objective is to have their unserviced land parcels converted to serviced subdivision plots with full legal title and to gain a vital net increase in the market values. The market valuations of the original land parcels and the new parcels/plots are also made public together with the percentage share of the total valuations. In addition, the project scheme should show every landowner the new land parcels that he/she will receive in exchange for his/her former land. The scheme should also indicate programme, cost estimation and land evaluation, a written statement that sets out the project objectives, the method of calculating the landowners' shares in the project, and the procedures to be used to implement the project. The projection of land value in the Klong Toei project has been projected as at 1994 using a 'regression' or so-

called 'a second-degree polynomial' method, as developed by Ryan and Joiner (1994). The Minitab statistical package has been exploited for projection of land value in the Klong Toei project while a 'market comparison value' method has been introduced to the Lad Krabang project.

6.4 APPLICATION AND RESULTS OF THE MULAR SYSTEM IN THE KLONG TOEI PROJECT

The Klong Toei project is located in an urbanised area of Bangkok where land parcels are irregular shaped and accessibility to the land is rather difficult. In addition, a large proportion of the land has been abandoned and has no network of public facilities, including no transportation links to the neighbouring developed areas. The thesis aims to show how LIS/GIS technology can help meet the need of city planners to apply urban land readjustment in such a type of urban environment. The Klong Toei project offers an alternative approach for applying LIS/GIS technology (eg the MULAR system) to urban land readjustment, whether the project will be implemented by the local government bodies or not. The overall feasibility study in the urban project covers the area of about 0.4 square kilometres.

6.4.1 Layout of master concept plan in the Klong Toei project

Figure 6.3 and Figure 6.4 illustrate physical conditions of the Klong Toei project in 1992 when the author carried out field completion. After analysing the existing physical conditions, two sites within the area were selected to be good examples for applying the MULAR system. The study areas are located on the west and east banks of the Paeng canal respectively. In 1992 'study area 1' was composed of vacant parcels while residential land use was dominant in 'study area 2', as shown in Figure 6.5.



Figure 6.3 A base map of the Klong Toei project in 1992.

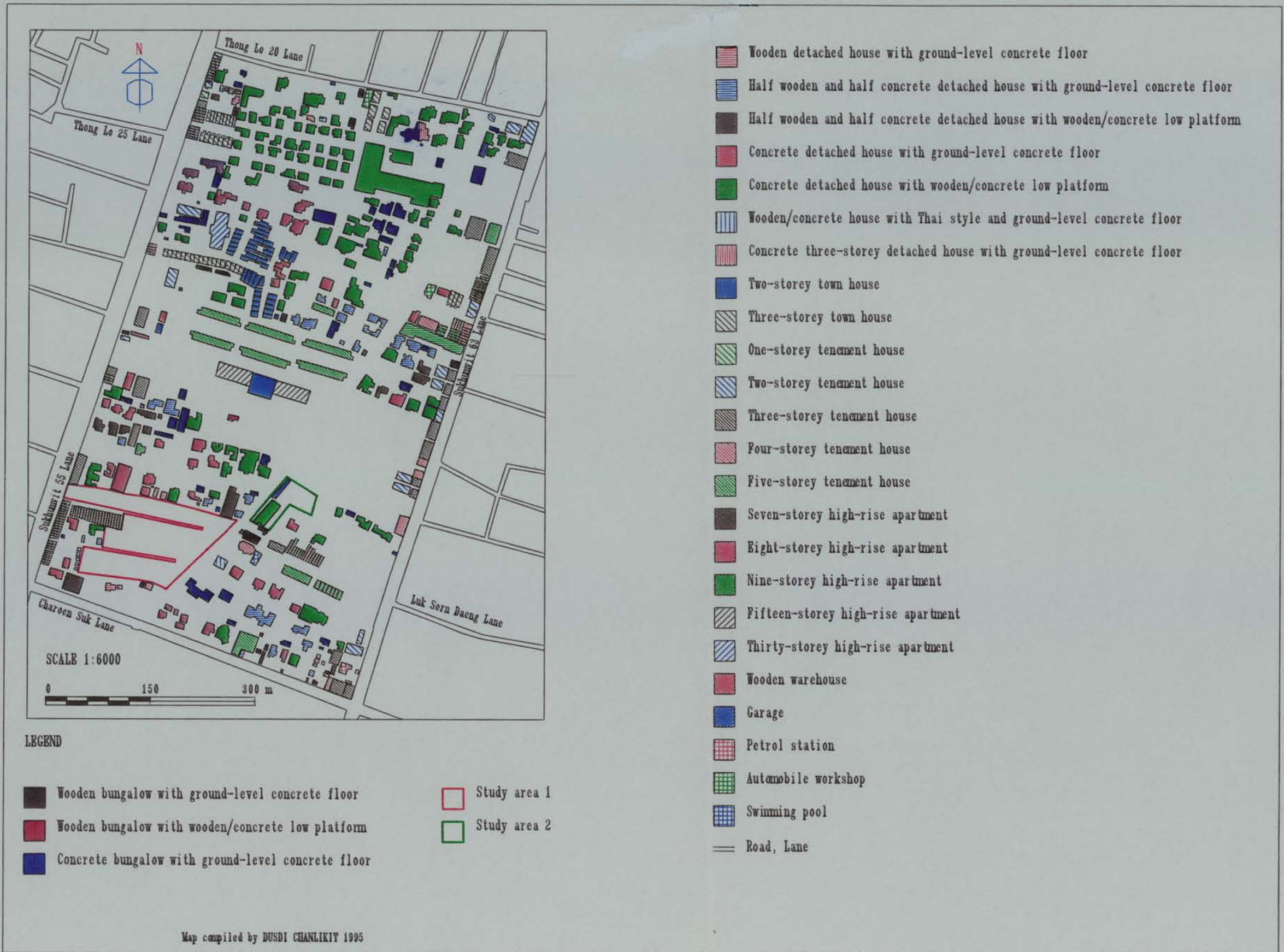


Figure 6.4 Building type of the Klong Toei project in 1992.



Figure 6.5 Land use of the Klong Toei project in 1992.

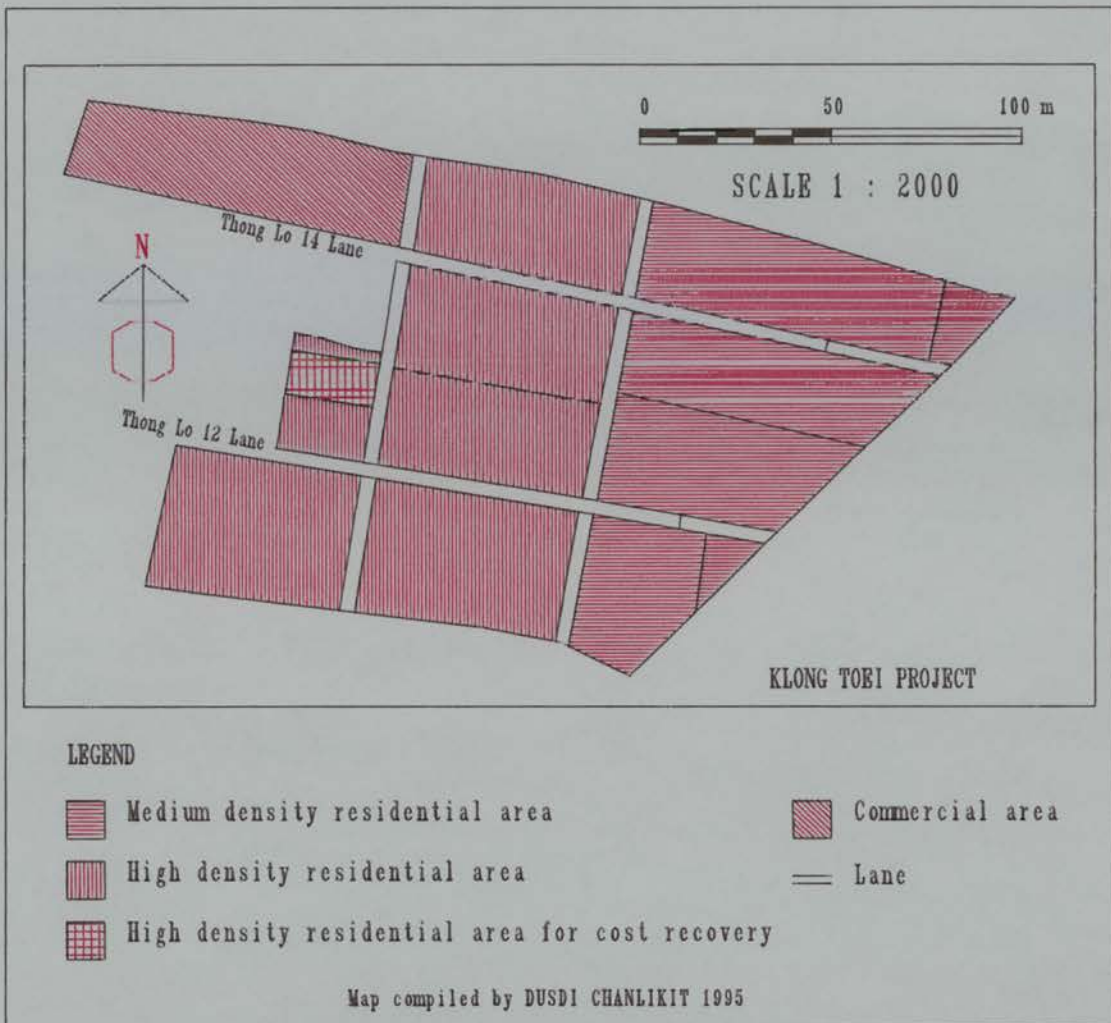


Figure 6.6 Layout of master concept plan (after replotting) in study area 1.

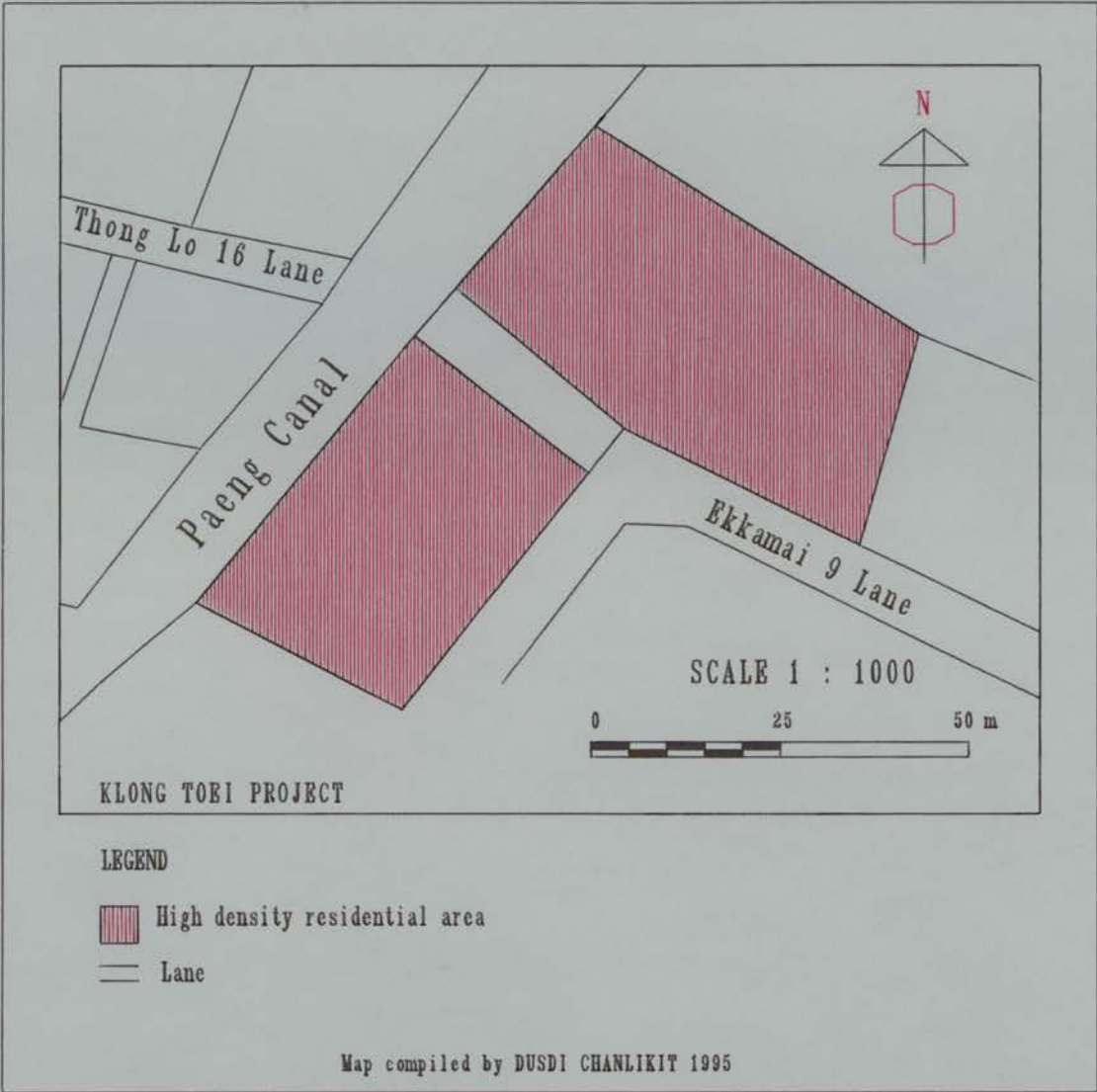


Figure 6.7 Layout of master concept plan (after replotting) in study area 2.

STUDY AREA 1

In the Klong Toei project, the master concept plan, Figure 6.6, has to be drawn in accordance with the current Bangkok Metropolis Plan (1992 - 1997) which designated the project area as a 'high density residential area'. Details showing the description on the use of land for medium density residential area which may not be permitted are shown in Appendix 6.7. There are certain decisions which city planners have to make for designing urban land readjustment in the 'study area 1'; these include:

- which characteristics are to be maintained, for example, Paeng canal, government land, and mosque;
- what shape the plots are to be, such as squares or rectangles, after land readjustment;
- how the land is to be returned to original landowners located as near as possible to their original locations;
- what is the suitable location of urban utilities;
- what is the suitable site of a reserved plot to be sold for cost recovery of the project expenses.

STUDY AREA 2

The design criterion in the 'study area 2' that city planners have to achieve is to provide a network of roads linked between the eastern and western side of the Paeng canal, as shown in Figure 6.7. In the Klong Toei project, data related to period of building are not available, and therefore, all these data have to be assumed.

6.4.2 Cost estimation and financial plan in the Klong Toei project

The project cost estimates have been calculated and obtained to an adequate level of detail and as realistically as possible. The proposed design concept for the study areas in the Klong Toei project is based on several considerations, such as drainage system,

and electricity supply. The detailed calculations on costs proposed for development of the 'study area 1' is shown in Table 6.2.

STUDY AREA 1

1) Drainage

Drainage is in the form of internal pipe culvert drains made of reinforced concrete with 0.60 m diameter along both sides of the new designed access roads, Figure 6.8. The drains lying in the east-west direction will be the water collector and discharged to the Paeng canal in the eastern part of the study area.

2) Electricity supply

The proposed high voltage electricity network in the study area will be tapped from the mains of existing project through 'Thong Lo 14' lane. The 24Kv high voltage lines are carried on concrete poles 12 m high and spaced every 50 metres, as shown in Figure 6.9. The 220v low voltage lines are carried on concrete poles, 8.5 m high and spaced every 20 metres on all roads. In addition 'Thong Lo 12' and 'Thong Lo 14' lanes are provided with 40w twin fluorescent bulbs spaced every 80 metres, Figure 6.10.

3) Public Telephones

The local public telephone booths are also provided as an indispensable urban utility for the dwellers in the study area and spaced every 150 metres while telephone cables are normally installed on the concrete electric poles (8.5 m high), Figure 6.11.

4) Road construction

The new 4 m paved access roads are designed to link between 'Thong Lo 12' and 'Thong Lo 14' lanes and are aligned north-south. They are also reorganising the existing irregular plots into regular, more preferable shapes and sizes for the proposed urban developing scheme (see Figure 6.6).

Table 6.2 Cost estimation for urban utilities in the Klong Toei project (study area 1).

ITEM	UNIT	COST/UNIT	NO. OF UNITS	COST	PERCENTAGE
DRAINAGE SYSTEM					
Concrete drain	Baht/m	1,800	1,126	2,026,800	43.48
ELECTRICITY SUPPLY					
Concrete electric pole, 12 m high, spaced 50 m	Baht/unit	3,294	9	29,646	5.57
Concrete electric pole, 8.5 m high, spaced 20 m	Baht/unit	3,000	64	192,000	
High voltage cable, 24 Kv	Baht/m	27	394	10,638	
Low voltage cable, 220v	Baht/m	10	1,126	11,260	
Twin fluorescent bulbs, 40w, spaced 80 m	Baht/unit	2,000	8	16,000	
PUBLIC TELEPHONES					
Telephone booth	Baht/unit	20,000	3	60,000	2.20
Coinbox telephone	Baht/unit	10,000	3	30,000	
Telephone cable	Baht/m	20	632	126,400	
ROAD CONSTRUCTION					
Paving	Baht/sq m	600	2,488	1,492,800	32.02
WATER SUPPLY					
Asbestos cement water-pipe with 3 inches diameter	Baht/m	80	1,126	900,080	2.32
Fire hydrants with 4 inches diameter, spaced 150 m	Baht/m	6,000	3	18,000	
CONTROL SURVEY					
				5,000	0.11
LAND TITLE DEEDS					
	Baht/unit	3,023	15	45,345	0.97
				4,040,209	
ADMINISTRATIVE COSTS (10 %)				404,021	8.67
INTEREST RATE OF 13 % (2 MONTHS)				96,292	2.06
CONTINGENCY BUDGET				121,206	2.60
			Total	4,661,728	100

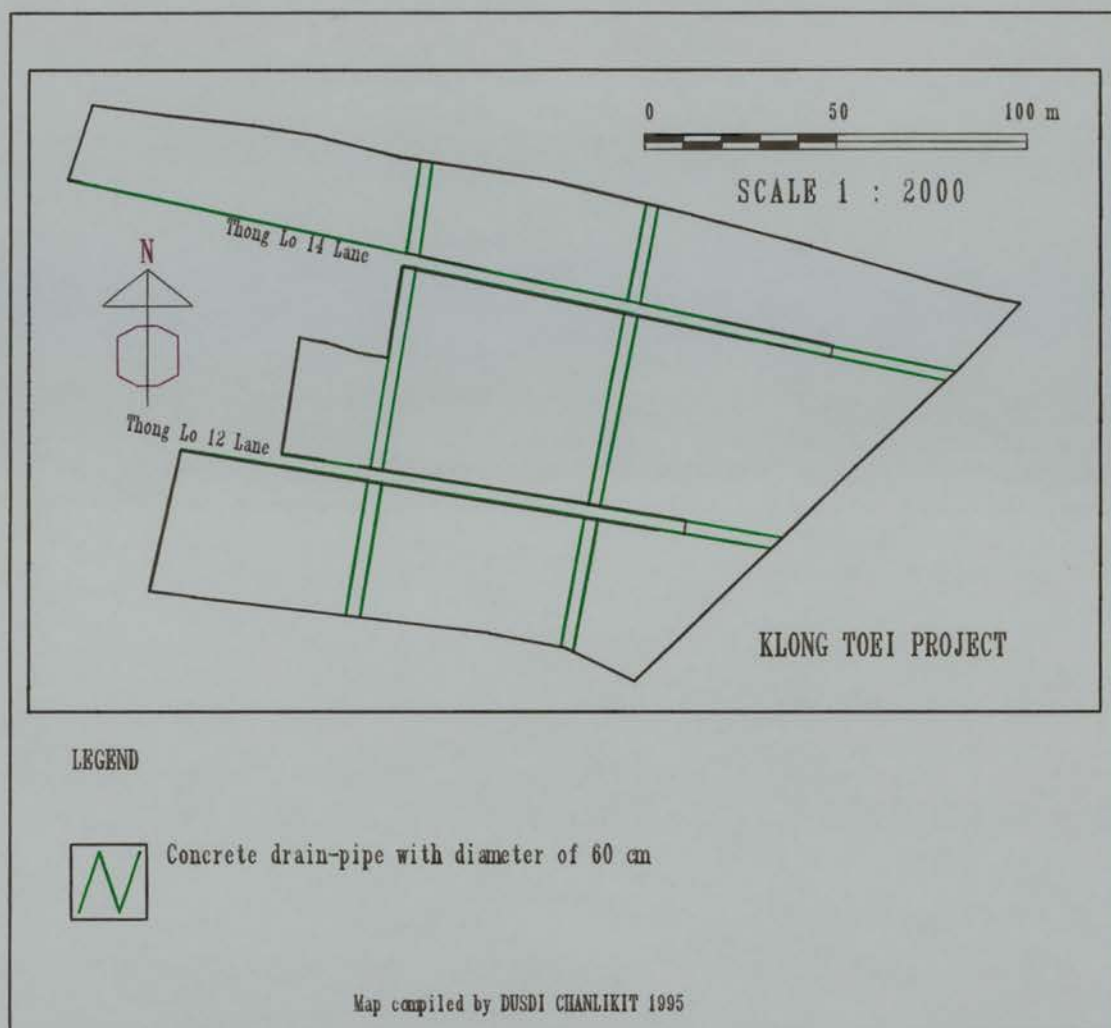


Figure 6.8 Proposed drainage network in the study area 1.

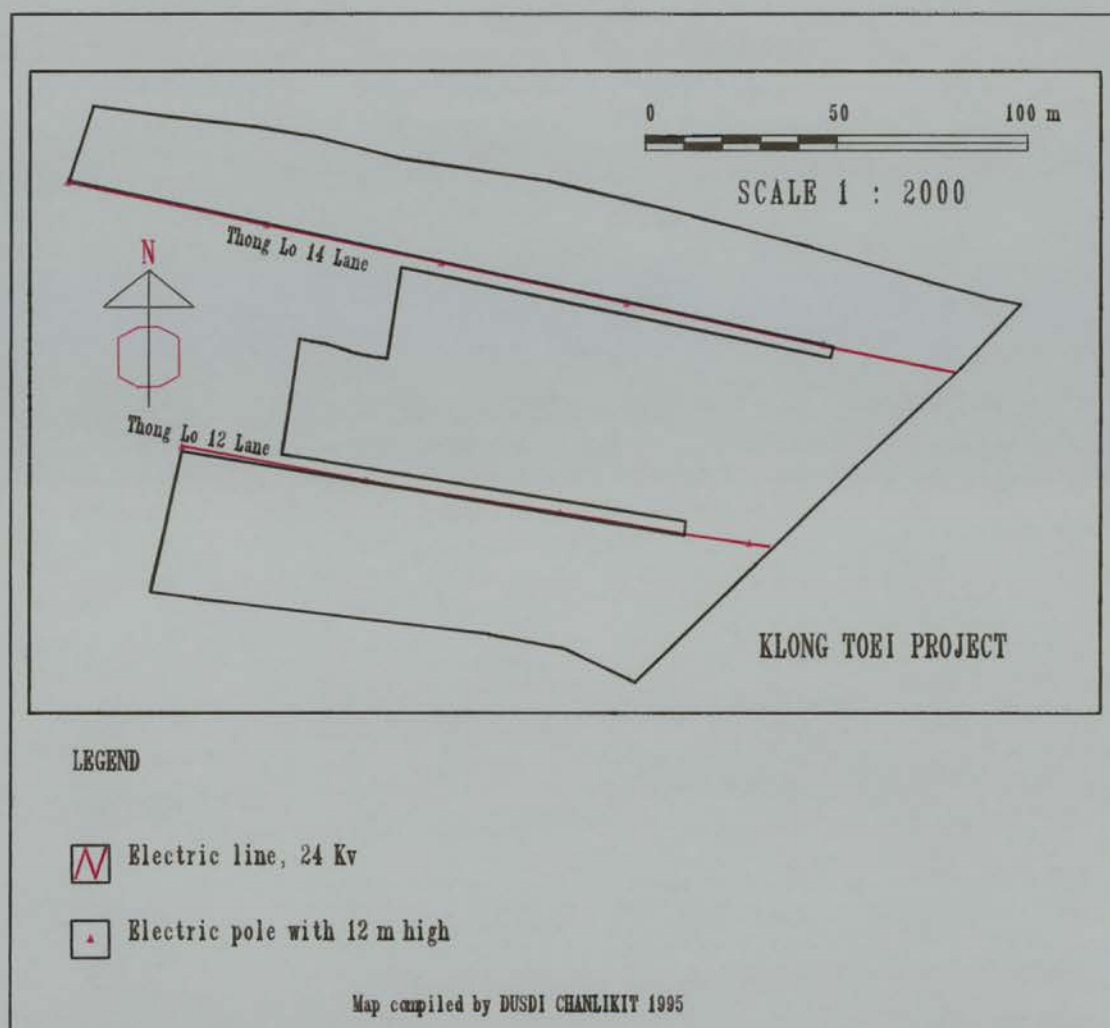


Figure 6.9 Proposed electric line and pole in study area 1.

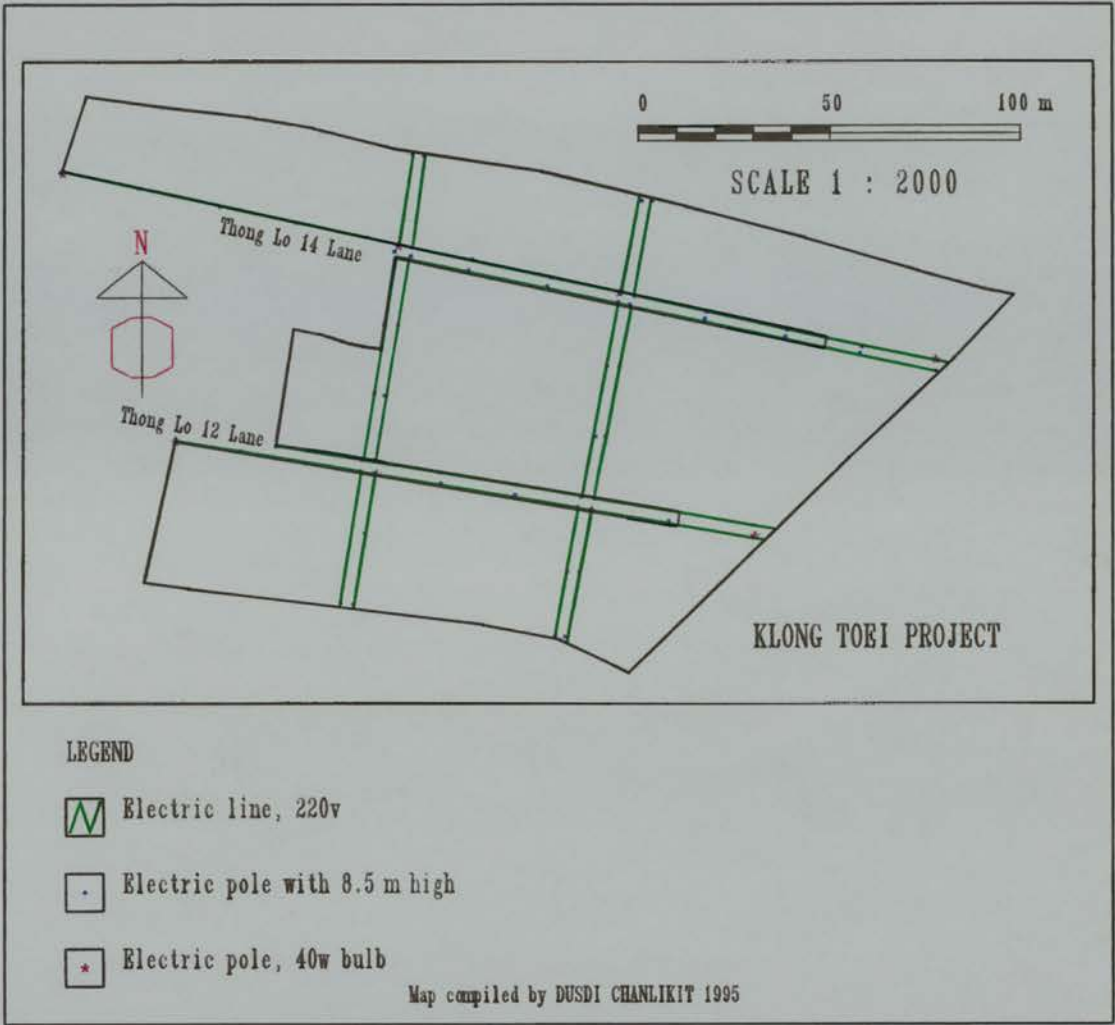


Figure 6.10 Electric line, pole, and twin fluorescent bulb in study area 1.

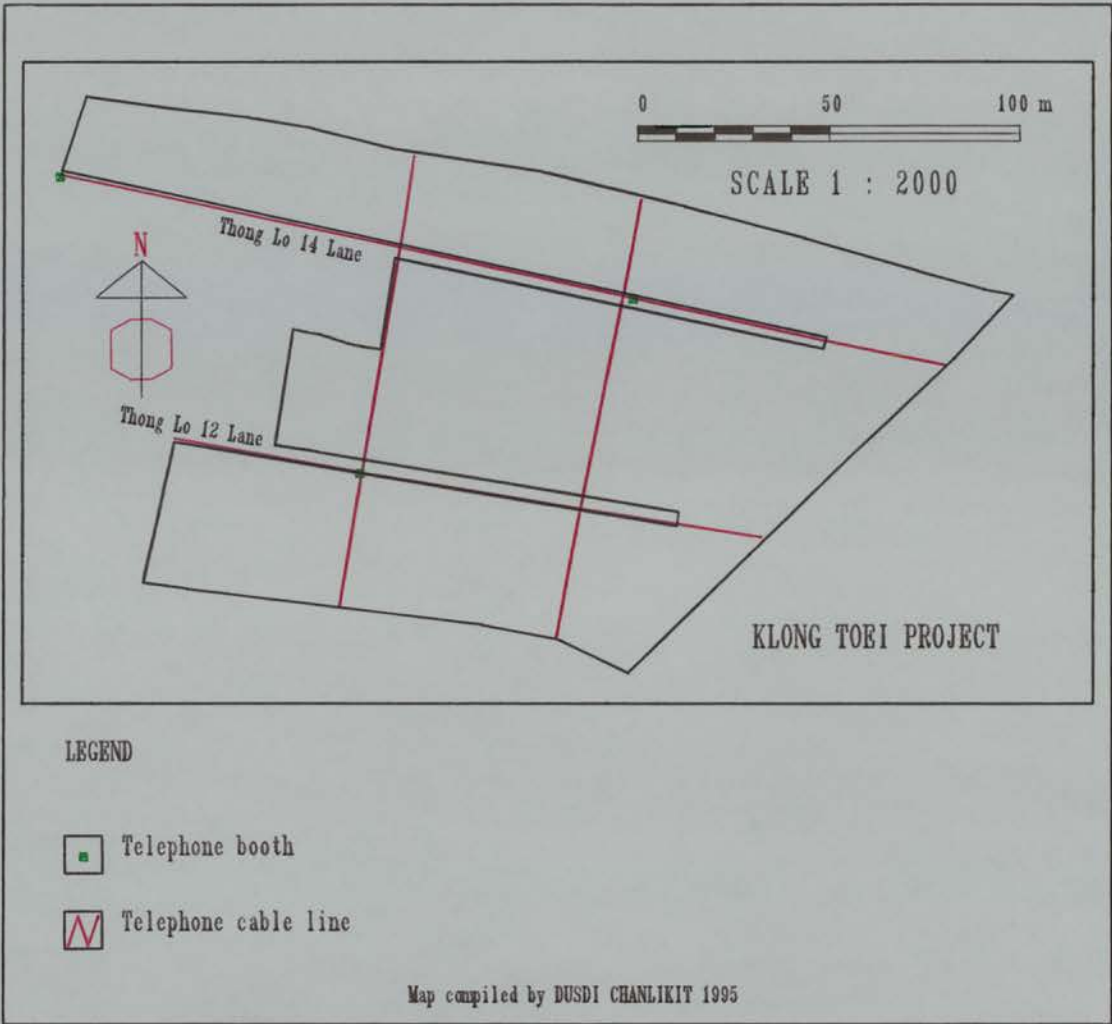


Figure 6.11 Telephone booth and cable in study area 1.

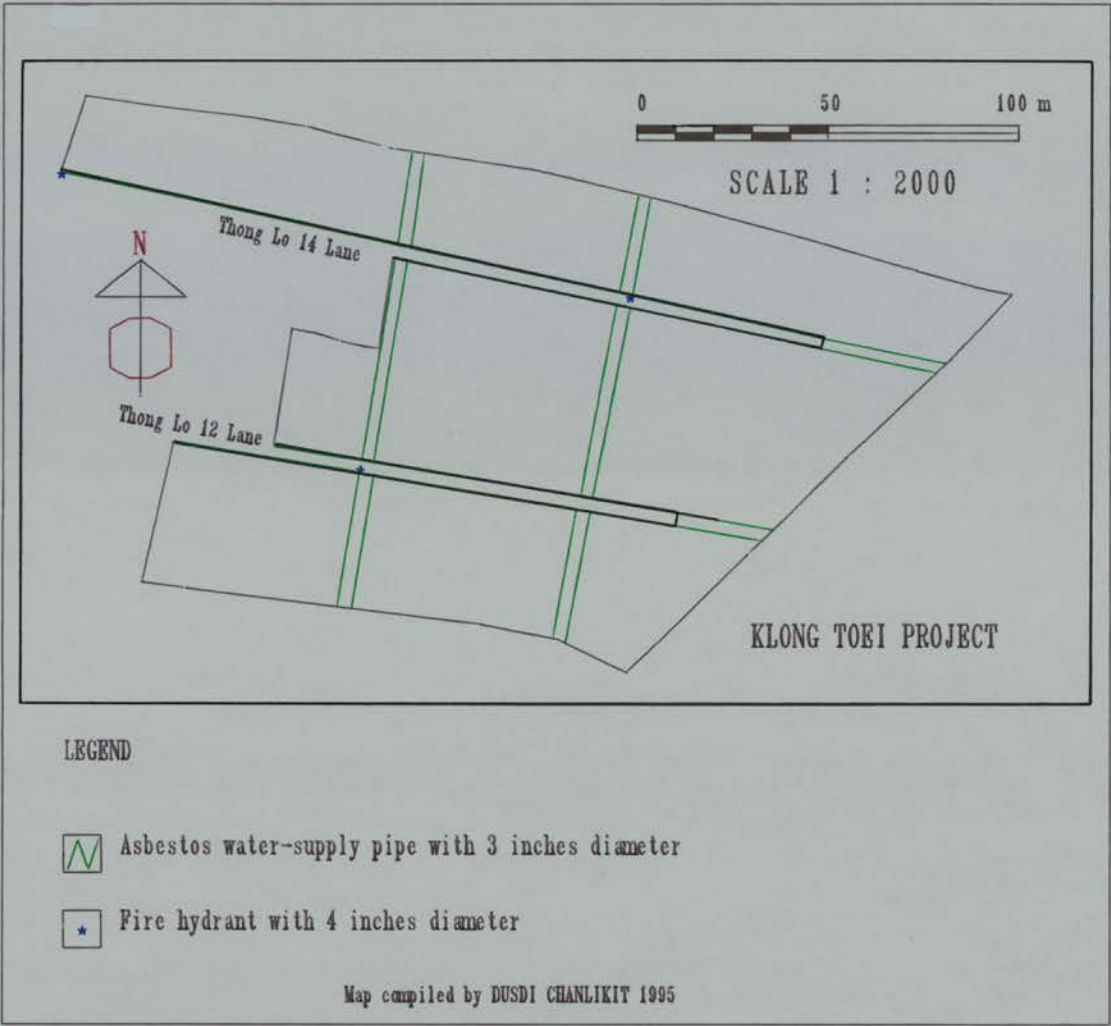


Figure 6.12 Water-supply pipe and fire hydrant in study area 1.

5) Water supply

For water supply, asbestos cement water-pipe with 3 inches diameter will be run to every land parcel, and water hydrants placed every 150 m, as depicted in Figure 6.12. The proposed water supply network will be tapped from the main existing line connected through the 'Thong Lo 14' lane.

6) Control survey

A reconnaissance and field completion have been carried out through the study areas for minor changes of buildings and public facilities as described in chapter 4, section 4.4.7.

7) Land title deeds

The study area is composed of 5 existing parcels which are to be divided into 15 parcels after the urban land readjustment process. The cost of issuing new land title deeds has to be included as a part of the project cost.

8) Administrative costs (10%)

The administrative cost, considered to be 10 percent of the sum of the urban utility cost, is composed of the costs of the control survey and of issuing new land title deeds.

9) Interest during construction (13%)

The interest of 13 per cent is charged during the construction of urban utilities so that all proposed urban utilities can be installed within a certain time. In this case, the construction of urban facilities is considered to be fulfilled within 2 months. The amount of interest for the project is calculated from the expenditure of installing urban utilities, control survey, issuing new land title deeds, and administrative cost.

10) Contingency budget

Contingency budget is considered to be a part of the project cost where the appropriate rate of 3 per cent is computed from the sum of installing urban utilities, control survey, and issuing new land title deeds.

In summary, the total cost of the project is 4,661,728 Baht. Infrastructure cost is calculated based on the layout plan and the standard of the MEA, TOT, and the NHA. Cost estimate of the drainage system represents 43.48 per cent while road construction consumes 32.02 per cent of the total cost. The proposed project is designed to install rudimentary urban utilities (eg road, telephone, electricity) within a period of two months. A parcel of land for 'cost recovery' is designated to be located in the 'high density residential area' whereby a 'faster sale' is more likely.

STUDY AREA 2

The fundamental calculation on costs for installation of urban facilities in the study area 2 is shown in Table 6.3.

1) Drainage

The reinforced concrete drains, with diameter of 0.60 m, are designed to lie along both sides of a new road; water will be collected and discharged to the Paeng canal in the western part of the study area.

2) Electricity supply

The proposed electricity cables in the study area will be tapped from the main existing network through 'Ekkamai 9' lane. The low voltage 220v cables will be carried on the 8.5 m high concrete poles, including 220v twin fluorescent bulbs; both are placed every 20 metres.

Table 6.3 Cost estimation for urban facilities in the Klong Toei project (study area 2).

ITEM	UNIT	COST/UNIT	NO. OF UNITS	COST	PERCENTAGE
COMPENSATION COSTS					
Demolishing one-thirds of a garage	Baht/sq m	340	60	20,400	6.40
DRAINAGE SYSTEM					
Concrete drain with diameter of 0.60 m	Baht/m	1,800	58	104,400	32.77
ELECTRICITY SUPPLY					
Concrete electric pole, 8.5 m high	Baht/unit	3,000	4	12,000	5.21
Low voltage cable, 220 v	Baht/m	10	58	580	
Twin fluorescent bulbs, 40w, spaced 20 m	Baht/unit	2,000	2	4,000	
ROAD CONSTRUCTION					
Paving	Baht/sq m	600	232	139,200	52.77
Footpath	Baht/sq m	314	87	27,318	
Curb	Baht/m	27	58	1,566	
LAND TITLE DEEDS	Baht/unit	3,023	3	9,069	2.85
Total				318,533	100.00

3) Road construction

A new access road (8 m width, with 1.5 m footpath and curb on both sides) is designed for the study area as a minor road network joined between the 'Thong Lo 16' and 'Ekkamai 9' lanes. It is evident that the new road provides linkage between the western and the eastern part of the Klong Toei project.

4) Land title deeds

According to evidence obtained from the DOL in 1992, the study area consists of two parcels of land belonging to the same landowner. A wooden garage is located in the upper plot while a nine-storey high-rise apartment block is constructed in the lower plot. Whenever the new road is applied to the study area, the two existing parcels have to be divided into three plots and the new land title deeds will be given to the landowner.

5) Cost of demolition of building

One-third of the wooden garage obstructs the proposed access road and so that part has to be demolished. As the date of building construction in the Klong Toei area is unknown, the year of construction has to be assumed from archival aerial photographic evidence. The aerial photographs for 1986 show the garage and therefore the garage is assumed to exist from this date. With the help of a depreciation table issued by the MOI in 1992, see Table 6.1, the construction cost for the garage has to be reduced by twenty per cent. The cost is equivalent to 425 Baht/sq m; after applying the depreciation factor, the construction cost is equal to 340 Baht/sq m. The gross floor area of the garage can be queried from the INFO, then 60 square metres of the southern edge of the garage has to be pulled down.

By this approach, all project cost will be imposed on the landowner who owns lands and he can donate the land, where the new access road is constructed, to the BMA through the process of transferring lot portion via land readjustment technique. In general, it is certain that the new access road not only creates an equilibrium of land

value between lands lie in both sides of the Paeng canal but helps smooth the traffic flow in the project area. It is noted that the construction cost of building the concrete bridge across the Paeng canal in the study area will be under the control of the Department of Public Works, MOI.

6.4.3 Replotting design in Klong Toei project

It is important to select the most suitable method for determining the replotting design. City planners have to be aware of many factors before commencing the replotting design, for example, conditions of project area, locations of replots, shapes of replots and lot boundaries. At the same time data on the present conditions have to be systematised so that the 'contribution ratio' can be determined, and so that appropriate replotting can be undertaken. When the replotting design is completed, the replotting design map is drawn and the replotting records are made.

STUDY AREA 1

Study area 1 is composed of five parcels of land, which are all vacant. Four parcels have long and narrow shapes or so-called 'ribbon urban development'. The remaining lot has been vacant land for a certain period with no developing scheme, Figure 6.13. Replotting design is undertaken by taking the above conditions (described in chapter 6, section 6.4.1) into account, and determining their existing shapes, locations and areas. Firstly, the 'actual replotting' is preceded by dividing the study area into nine main blocks by a network of new roads. Secondly, the range and location of new lots after the project is estimated and plotted using the editing facilities embedded in the MULAR system. Thirdly, replots are allotted, balancing all sites in the replotting area. A parcel is also allocated as a 'land for cost recovery' of the project and it is located in the high density residential area with good surroundings, as shown in Figure 6.14. The contribution ratio of the land where landowners give away portions of their land for the whole project is considered to be 7.25 per cent.

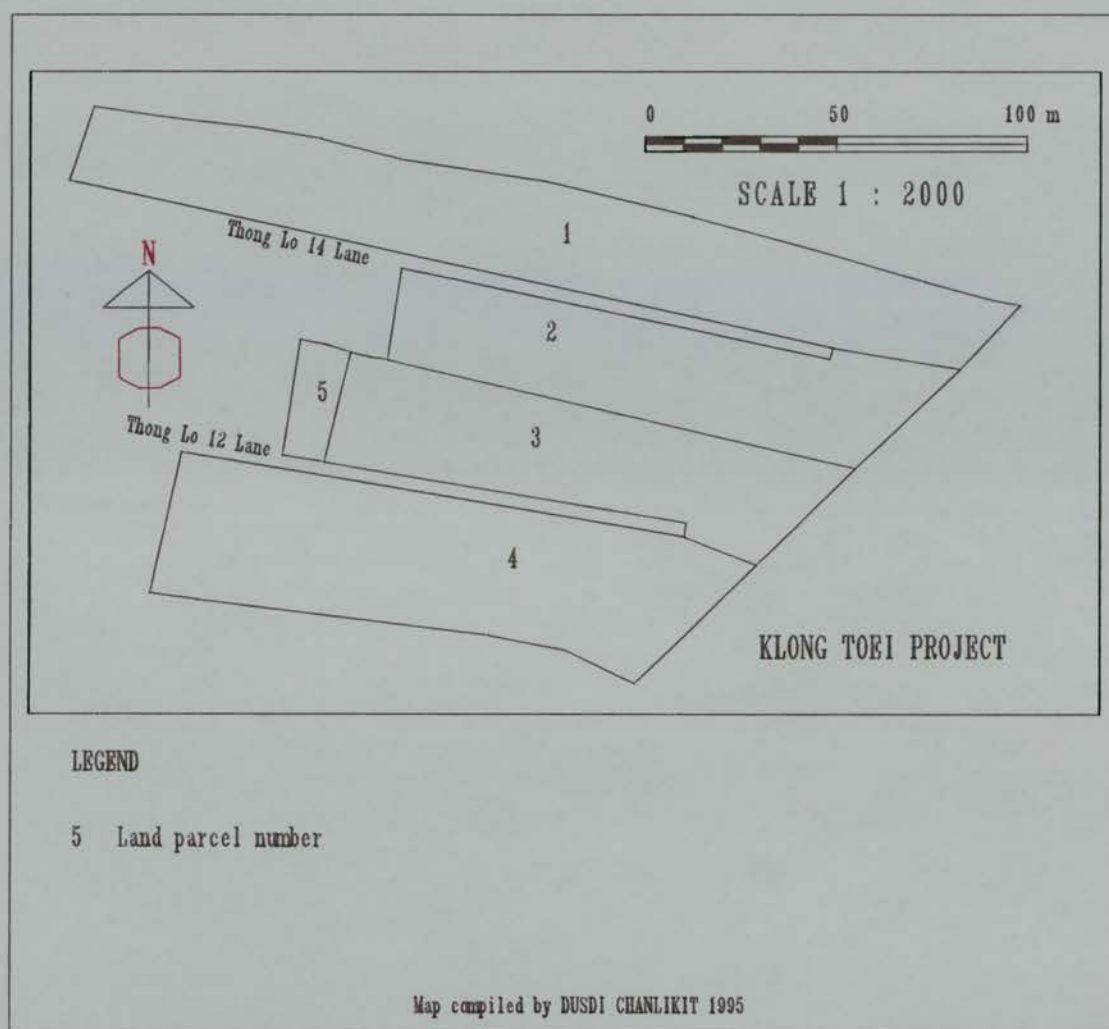


Figure 6.13 Numbering of land parcels before replotting.

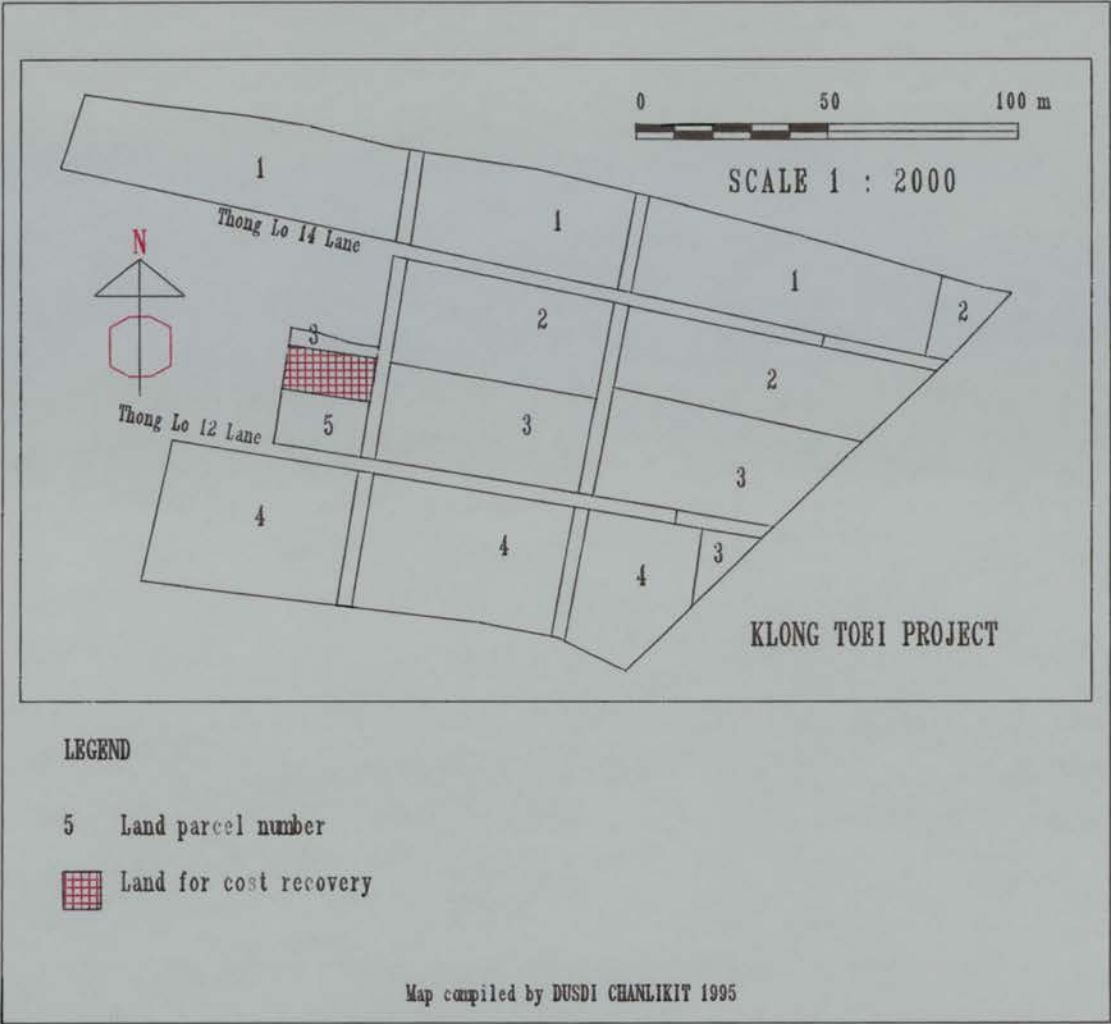


Figure 6.14 Numbering of land parcels after replotting.

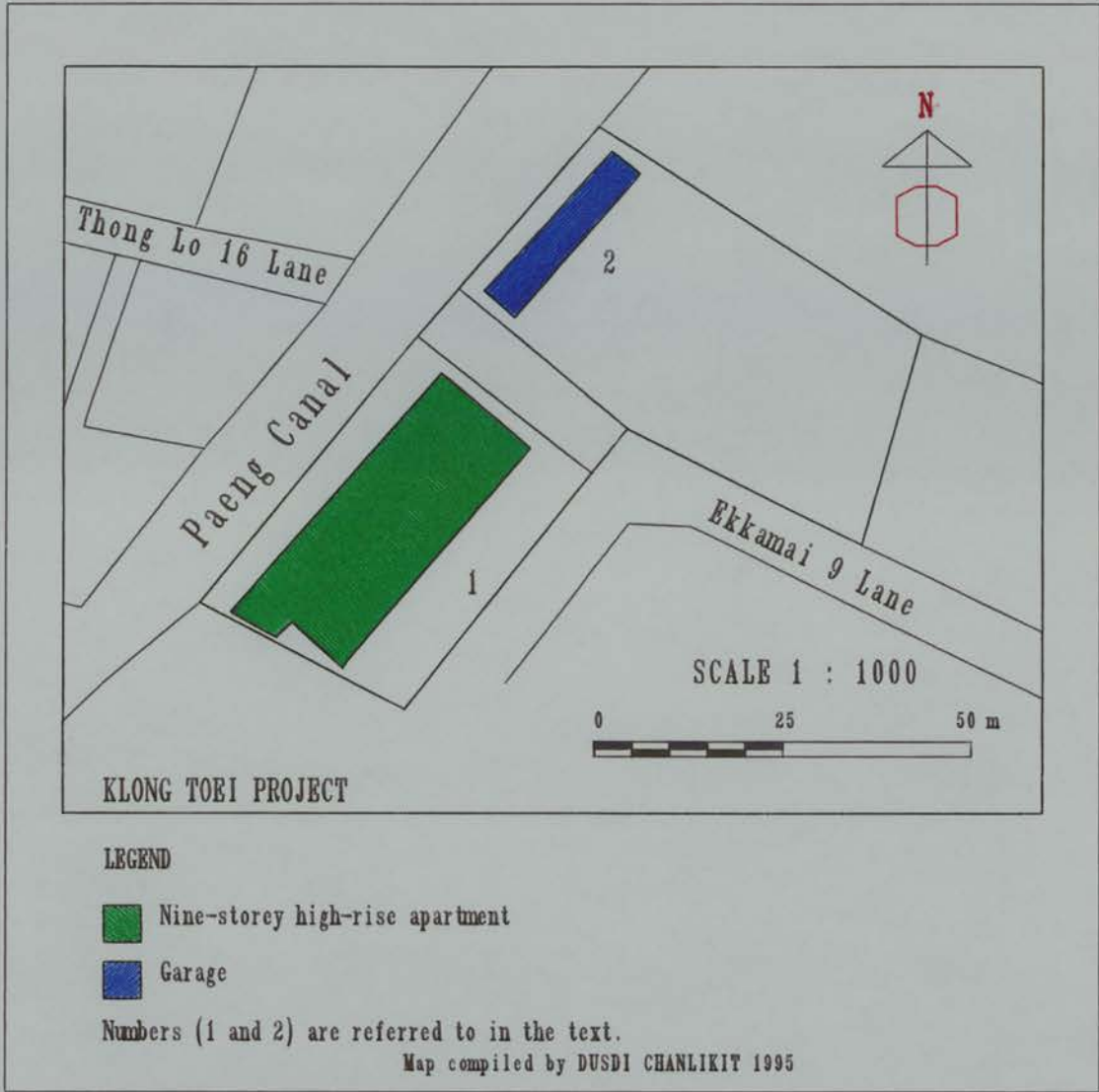


Figure 6.15 A proposed building in study area 2.

STUDY AREA 2

The study area consists of two plots: in the southern plot (number 1) the existing activity is residential while the northern plot (number 2) is utilised as a garage, Figure 6.15. A new road, 8 m width, is suggested using editing facilities in the MULAR system to provide a connection between the 'Thong Lo 16' and 'Ekkamai 9' lane. By doing so, the existing plots are divided into three parts and the existing activities are still maintained.

6.4.4 List of new parcels and valuations in the Klong Toei project

Appraisal of land value before and after land readjustment is very important. The readjusted plots must be redistributed in compliance with the original area or price of the original plots; after the readjustment, landowners who suffer losses will be compensated by those who enjoy the benefits. From the land values within the Klong Toei project collected since 1976 by the DOL, graphs have been processed by the author and projected to 1994 using a 'second-degree polynomial' method, as shown in Figure 6.16.

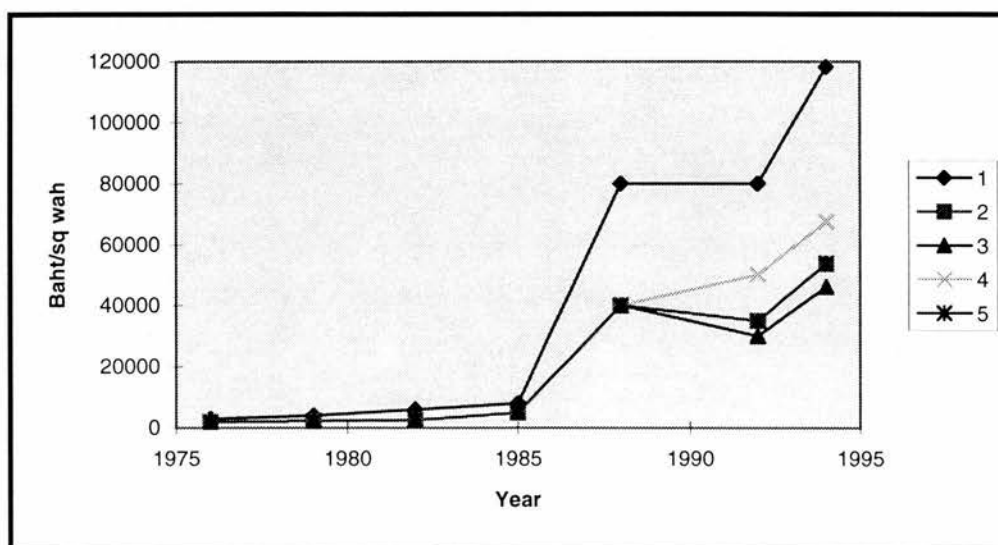


Figure 6.16 The increasing in land value as projected to 1994 in study area 1. (The values for parcel 2 and 5 are identical.)

STUDY AREA 1

The projected land values of all land in 1994 is illustrated and adjusted in Table 6.4 using the raw data provided by the DOL, with the help of the Minitab statistical package.

Table 6.4 Adjusted land values as at 1994 in the Klong Toei project (study area 1).

Parcel number	1976	1979	1982	1985	1988	1992	1994 Projected land value	1994 Adjusted land value
1	3,000	4,000	6,000	8,000	80,000	80,000	118,217	119,000
2	2,000	2,200	2,500	5,000	40,000	35,000	53,690	68,000
3	2,000	2,200	2,500	5,000	40,000	30,000	46,121	68,000
4	2,000	2,200	2,500	5,000	40,000	50,000	67,560	68,000
5	2,000	2,200	2,500	5,000	40,000	35,000	53,690	68,000

The land value data in the Klong Toei project were periodically collected and assessed by the DOL during the period 1976 to 1992. All the data have been loaded in the ORACLE package, retrieved by the MULAR system and presented cartographically (Figure 6.17). After introducing urban land readjustment in the study area, it is evident that all roads can provide access to all proposed land parcels which are divided into well-proportioned sizeable plots with considerable and fair opportunity for the land development scheme because all urban facilities are provided to all land in the project. Thus, all land values located in the southern part of 'Thong Lo 14' lane are adjusted to the same value, Figure 6.18.

Table 6.5 shows existing condition of land in study area 1, in 1992, before the author undertook the urban land readjustment while the data related to land after alterations in size and value are depicted in Table 6.6. In addition the increases in land value after the project are given in Table 6.7. It is noted that basic financial resource of urban land readjustment in the site is obtained by selling cost recovery land where the proposed land value is equivalent to 68000 Baht per square wah.

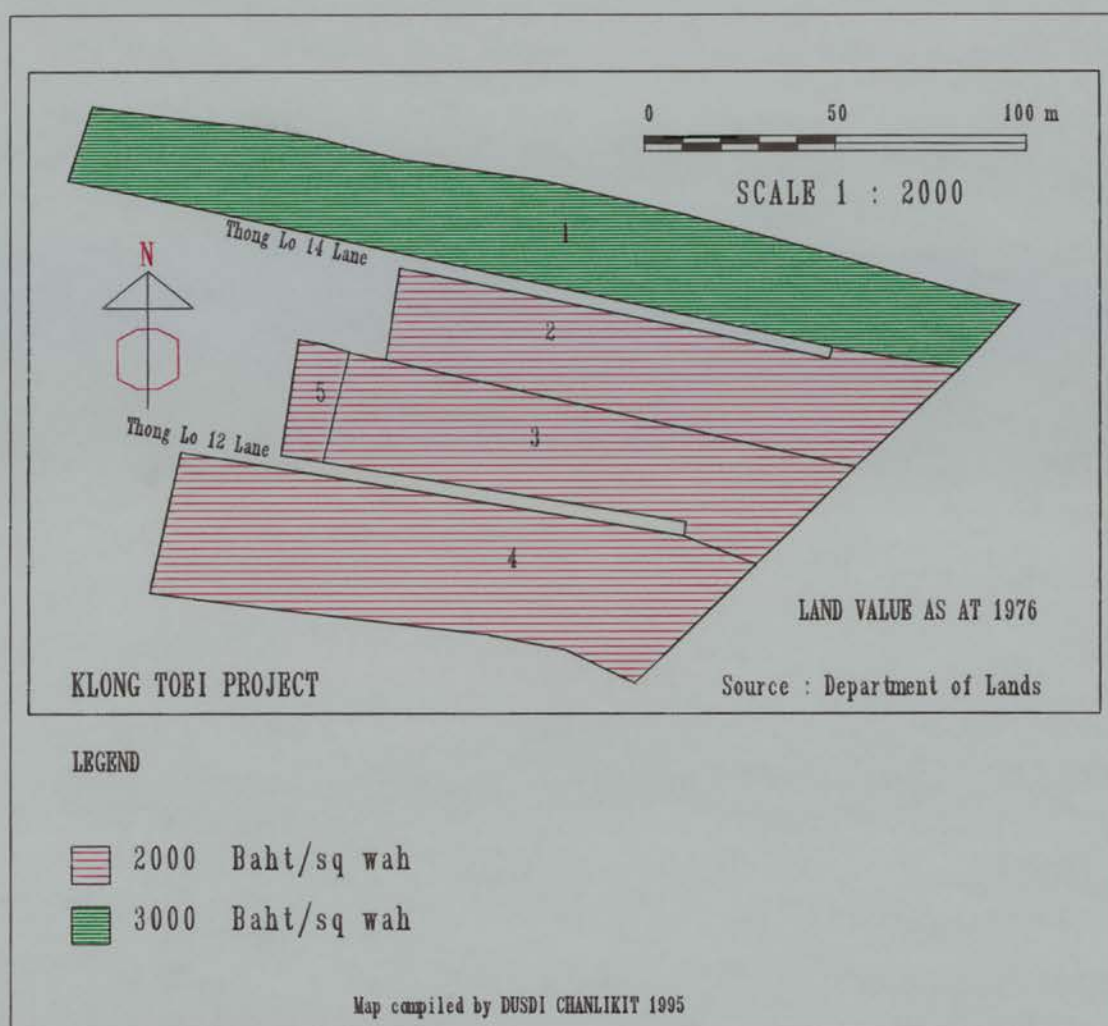


Figure 6.17 Land value in study area 1.

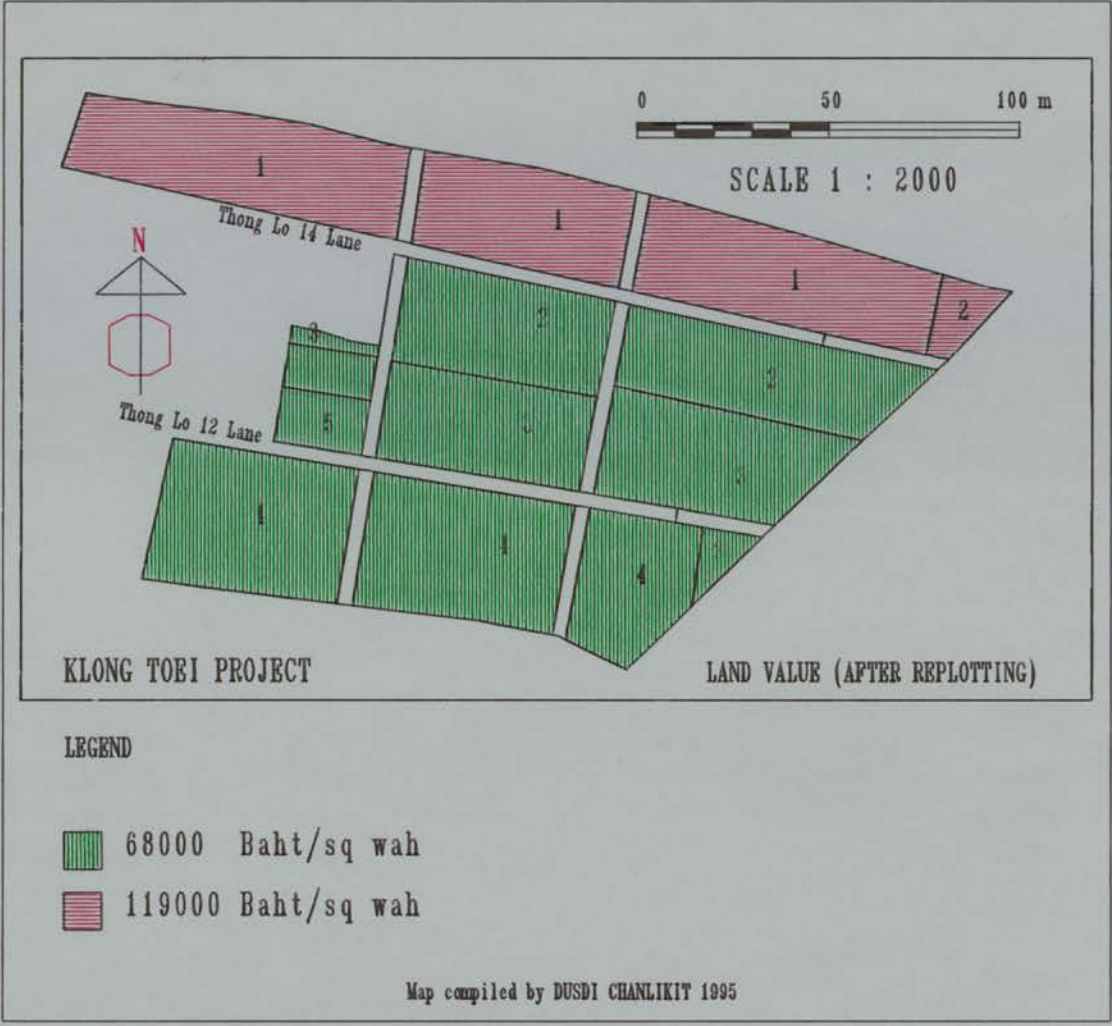


Figure 6.18 Proposed land value as at 1994 in study area 1.

Table 6.5 Land values before introducing the urban land readjustment (study area 1).

Parcel number	Area sq wah	Land value Baht/sq wah	Land value Baht
1	1463.6855	80,000	117,094,840
2	902.1895	35,000	31,576,633
3	874.8633	30,000	26,245,899
4	1296.6153	50,000	64,830,765
5	94.2393	35,000	3,298,376
Total	4631.5929		243,046,513

Table 6.6 Land values after introducing the urban land readjustment (study area 1).

Parcel number	Area Sq wah	Land value Baht/sq wah	Adjusted land value Baht/parcel	Total value Baht	Land to be returned to landowner (sq wah)
1	514.4325	119,000	61,217,468	161,546,392	1357.5327
1	365.4625	119,000	43,490,038		
1	477.6377	119,000	56,838,886		
2	63.2638	119,000	7,528,392	60,126,052	836.7588
2	368.3575	68,000	25,048,310		
2	405.1375	68,000	27,549,350		
3	350.9025	68,000	23,861,370	55,176,179	811.4144
3	405.045	68,000	27,543,060		
3	36.7944	68,000	2,502,019		
3	18.6725	68,000	1,269,730		
4	466.5725	68,000	31,726,930	81,775,379	1202.5791
4	465.36	68,000	31,644,480		
4	270.6466	68,000	18,403,969		
5	87.4046	68,000	5,943,513	5,943,513	87.4046
Total				364,567,515	4295.6896

Table 6.7 Land values before and after introducing the urban land readjustment (study area 1).

Parcel number	Land value (Before) Baht/parcel	Land value (After) Baht/parcel	Increased land value Baht/parcel	Multiplied
1	117,094,840	161,546,392	44,451,552	1.38
2	31,576,633	60,126,052	28,549,419	1.9
3	26,245,899	55,176,179	28,930,280	2.1
4	64,830,765	81,775,379	16,944,614	1.26
5	3,298,376	5,943,513	2,645,137	1.8
Total	243,046,513	364,567,515	121,521,002	1.5

STUDY AREA 2

Data related to land value in the 'study area 2' have been periodically collected and assessed by the DOL, Thailand, from 1976 to 1992. The projected land value of the proposed two plots has been achieved by using the Minitab statistical package, Table 6.8. It is clear that after introducing land readjustment, the land value will be increased with a minimum rate of 41,000 Baht/sq wah, as adjusted in the Table 6.8, because the two plots are now better provided with urban facilities like electricity, and access to the neighbouring areas can be made possible either by using the 'Thong Lo 16' or 'Ekkamai 9' lane assuming that a concrete bridge has been constructed. The list of the land before and after is shown in Table 6.9; by this approach, the landowner can either donate the parcel of land (proposed as a new road) with no reserved land for cost recovery (see also Figure 6.20) or sell a small piece of land (7.77 sq wah) to compensate for the cost of providing the urban facility which is equivalent to 318,533 Baht. However, it is preferable that the project cost be a burden on the landowner as it is rather a small amount of budget comparing to the increase in land value which he will gain after the project.

Table 6.8 Adjusted land values as at 1994 in the Klong Toei project (study area 2).

Parcel number	1976	1979	1982	1985	1988	1992	1994 Projected land value	1994 Adjusted land value
1	2,000	2,600	3,000	8,000	30,000	30,000	40,631	41,000
2	2,000	2,600	3,000	8,000	30,000	30,000	40,631	41,000

Table 6.9 The size of land before and after introducing urban land readjustment in study area 2.

Parcel number	Area (Before) Sq wah	Area (After) Sq wah
1	342.755	322.414
2	471.0528	432.498
Total	813.8078	754.912

In brief, in study area 1 the provision of urban utilities will have a great impact, by reducing in size of all plots proportionally by 7.25 per cent but increasing their value by 1.5 times. In study area 2, donation of a piece of land for public road network is

suggested; the donated land represents 7.21 per cent of the total area. On average the remaining land increases in value after introducing land readjustment by 1.37.

6.5 APPLICATION AND RESULTS OF THE MULAR SYSTEM IN THE LAD KRABANG PROJECT

The Lad Krabang project is situated in a suburban area of Bangkok, Lad Krabang district, where there is the potential for an increase in land value with a change from agricultural to urban land use. The main existing land use is grass and rice cultivation. Transportation in the area can be improved using the Ratpatthana road, Lum Nai So and Nang canal, Figure 6.19. Although the area is located in a low-lying plain (see Figure 6.2), it doesn't have serious flooding because it lies within the King's Dike project. The study area occupies about 685.65 rai or 110.184 hectares (excluding the Ratpatthana road). There are 27 parcels in total; 23 parcels are privately owned land and the remaining parcels are the NHA owned land. However, the area is deemed to yield great potential for infrastructure and building development as it is in proximity to community housing projects developed by the NHA. The thesis aims to suggest an alternative approach (eg the MULAR system) in order to tackle technical problems in land readjustment procedure caused by city planners, whether the Lad Krabang project will be selected to implement land readjustment by local government agencies or not.

6.5.1 Layout of master concept plan in Lad Krabang project

In the Lad Krabang project, in compliance with the General Plan, the proposed master concept plan is for 'medium and low density residential area'. Details describing the explanation on the use of land for 'low density residential purpose' which may be prohibited are depicted in Appendix 6.8.



Figure 6.19 Base map of the Lad Krabang project.

The design criteria to be fulfilled in the project are as follows:

- to provide new access roads to all parcels,
- to provide a network of other urban utilities (eg electricity, telephone, water supply),
- to provide urban facilities (eg school, playground, park).

The decisions which city planners have to make for the design of urban land readjustment are:

- which main characteristics to be retained in the project area, for instance, orchards;
- the size of the plots before and after land readjustment;
- the minimum movement of landowners from their original lands;
- the suitable site of urban utilities;
- the location of urban facilities;
- the suitable site of a reserved portion which is sold to generate income to partly or wholly compensate project expenses.

The layout plan of the study area is designated according to the criteria mentioned above; therefore, the urban facilities were first placed in areas where existing land value was low in 1992 and at distance in both directions from the main existing road (the Ratpatthana road). There are two principal reasons for doing this. Firstly, the parcels which have high price and are adjacent to the existing communication network will be selected to be 'cost recovery land' while land yielding low price and lacking a communication network can be allocated as urban facilities for the community. Secondly, the urban facilities should be placed at the distance (eg 300 m) from the main congested road for conservational and safety reasons.

With the help of the MULAR system, the 'candidate land' which is suitable for urban facilities is selected, as shown as shaded areas in Figure 6.20. The next step is to locate where these facilities should be placed in the candidate land; also three types

of roads with different right of way are provided to the study area to ensure that all proposed parcels can be accessed and traffic problems in the neighbourhood solved, Figure 6.21. The standard of the roads and size of urban facilities are set and adapted according to the NHA standard. The study area is roughly plotted and new land use is given to the proposed new plots. In addition, two plots are set aside to be recovery land for the project cost, Figure 6.22.

6.5.2 Cost estimation and financial plan in the Lad Krabang project

As the study area in the Lad Krabang project is situated on a low-lying plain where several types of economic fruits are grown, the additional costs of land fill and of removing houses and trees are taken into account as project costs, Table 6.10.

1) Compensation costs

Figure 6.23 shows the proposed new location of 5 wooden buildings which have to be moved to new suitable surroundings after a new network of roads has been designed to the study area. The compensation cost of removing each house is found from the depreciation table released by the MOI in 1992 (see Table 6.1). In the project, one bamboo, eleven coconut, and one mango tree are removed (Figure 6.24) because they impede the proposed network of roads and the compensation cost is integrated in the project cost according to the compensation cost of tree removal set by the Ministry of Agriculture and Co-operatives (see MAC, 1991, Appendix 4.8). The data related to the removal of houses and trees can be queried in ORACLE via X window environment.

2) Drainage

Internal pipe culvert drains made of reinforced concrete with 100 cm diameter are placed along both sides of the major arterial roads with 20 m right of way while drains with diameter of 60 cm are allocated to both sides of the remaining roads, as shown in Figure 6.25. All drains will require sufficient slope to flow to the manholes

provided every 10 m and used domestic water from houses in the study area will be discharged to the Lum Nai So and Nang canal. Water drainage, even in the rainy season, will not cause any serious problem, due to the presence of the canals bounding the site on the north and east.

3) Earthworks

As the whole of the study area is located on a low-lying plain with the average height of about 0.5 m above the mean sea level (MSL) and different kind of bushes and trees grow in profusion, clearing and earth fill are required. Using AP190 analytical stereoplotter, a set of height data of the terrain were collected on a 20 metre square grid. The data were transferred to the VAX environment and, using a FORTRAN program written by the author, the volume of earth fill at the given height (1.5 metres above MSL) was computed, as shown in Appendix 6.9.

4) Electricity supply

The proposed high voltage electricity network will be tapped from the existing main network which lies along the southern part of Lum Nai So canal. The 24 Kv high voltage cables are carried on concrete electric poles 12 m high and spaced every 50 metres, Figure 6.26. The 220 v low voltage cables are carried on 8.5 m high concrete electric pole, spaced 20 m apart, on all roads. Moreover, twin fluorescent 40 w bulbs are provided along all roads, placed on the 8.5 m concrete poles and spaced every 80 m, Figure 6.27.

5) Public telephones

The local public telephone booths, coinbox-telephone type, are provided with sufficient density, especially in the land recovery areas where commercial activities are likely to take place while telephone cables are carried on the concrete electric poles (8.5 m high), as shown in Figure 6.28.

Table 6.10 Cost estimation for urban utilities in the Lad Krabang project.

ITEM	UNIT	COST/UNIT	NO. OF UNITS	COST	PERCENTAGE
COMPENSATION COSTS					0.04
Compensation cost for removing houses			5	145,000	
Compensation cost for removing trees			13	8,500	
DRAINAGE SYSTEM					10.41
Concrete drain-pipe with diameter of 1.00 m	Baht/m	3,500	7,499	26,246,500	
Concrete drain-pipe with diameter of 0.60 m	Baht/m	1,800	5,826	10,486,800	
EARTHWORKS					53.24
Clearing	Baht/rai	285	689	196,365	
Land fill (1.5 m above the MSL)	Baht/cubic m	180	1,042,925	187,726,500	
ELECTRICITY SUPPLY					0.8
Concrete electric pole, 12 m high, spaced 50 m	Baht/unit	3,294	95	312,930	
Concrete electric pole, 8.5 m high, spaced 20 m	Baht/unit	3,000	668	2,004,000	
High voltage cable, 24 Kv	Baht/m	27	4,419	119,313	
Low voltage cable, 220 v	Baht/m	10	13,325	133,250	
Twin fluorescent bulbs, 40w, spaced 80 m	Baht/unit	2,000	100	200,000	
Transformer, 160 Kv	Baht/unit	65,900	1	65,900	
PUBLIC TELEPHONES					0.07
Telephone booth	Baht/unit	20,000	7	140,000	
Coinbox telephone	Baht/unit	10,000	7	70,000	
Telephone cable	Baht/m	20	2,154	43,080	
ROAD CONSTRUCTION					17.03
Paving	Baht/sq m	600	80,238	48,142,800	
Footpath	Baht/sq m	314	32,393	10,171,402	
Curb	Baht/m	140	12,924	1,809,360	
WATER SUPPLY					0.74
Drilling and elevated tank with 50 cubic metres	Baht/unit	700,000	2	1,400,000	
Asbestos cement water-pipe with 4 inches diameter	Baht/m	100	4,215	421,500	
Asbestos cement water-pipe with 3 inches diameter	Baht/m	80	8,452	676,160	
Fire hydrants with 4 inches diameter, spaced 250 m	Baht/unit	6,000	18	108,000	
CONTROL SURVEY				20,000	0.01
LAND TITLE DEEDS	Baht/unit	3,023	50	151,150	0.04
LANDSCAPE DESIGN AND PLANTING TREES				3,000,000	0.85
				293,798,510	
ADMINISTRATIVE COSTS (10%)				29,379,851	8.32
INTEREST RATE OF 13 % (6 MONTHS)				21,006,593	5.95
CONTINGENCY BUDGET				8,813,955	2.5
			Total	352,998,909	100

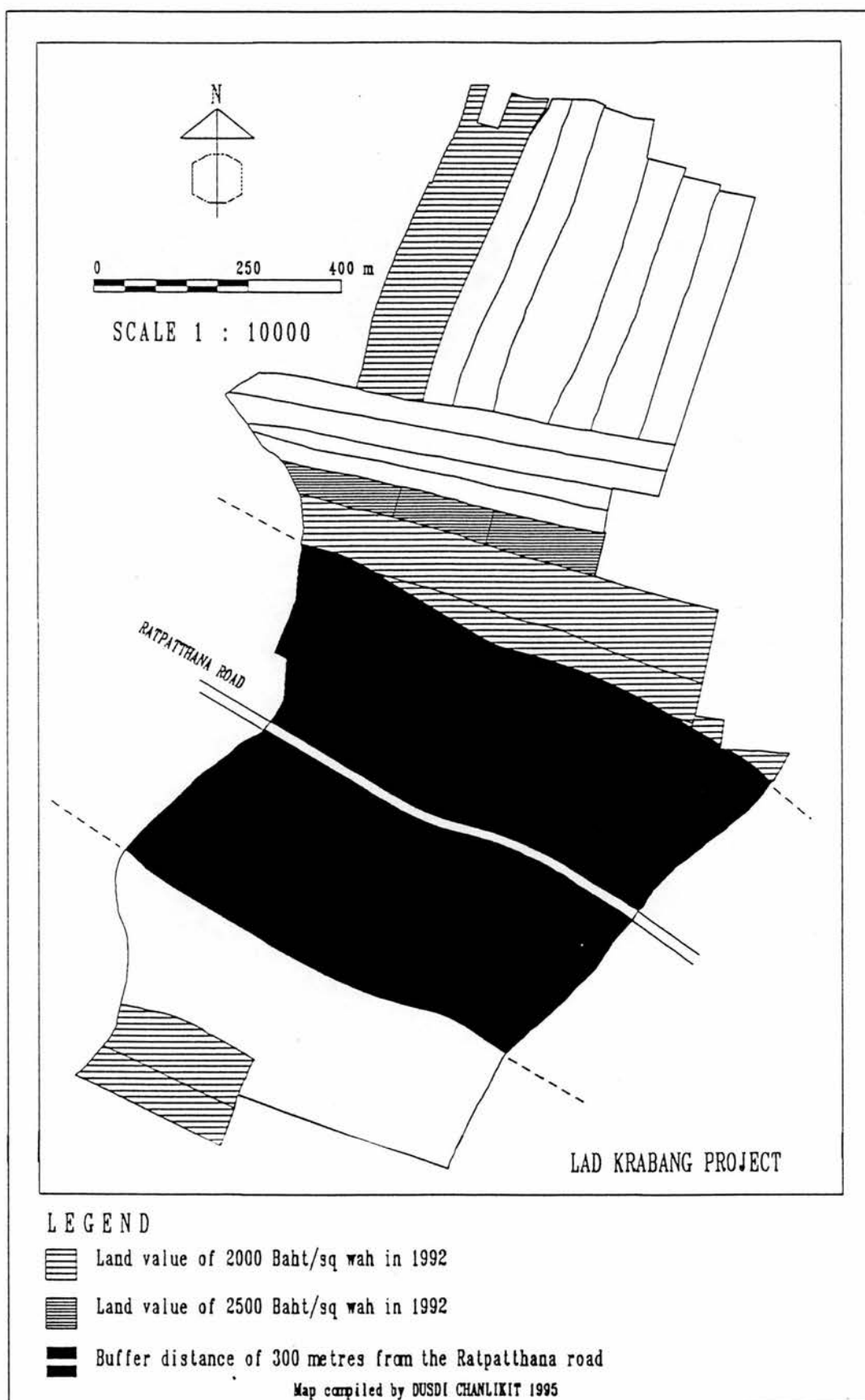


Figure 6.20 Land values and buffering of an existing road.

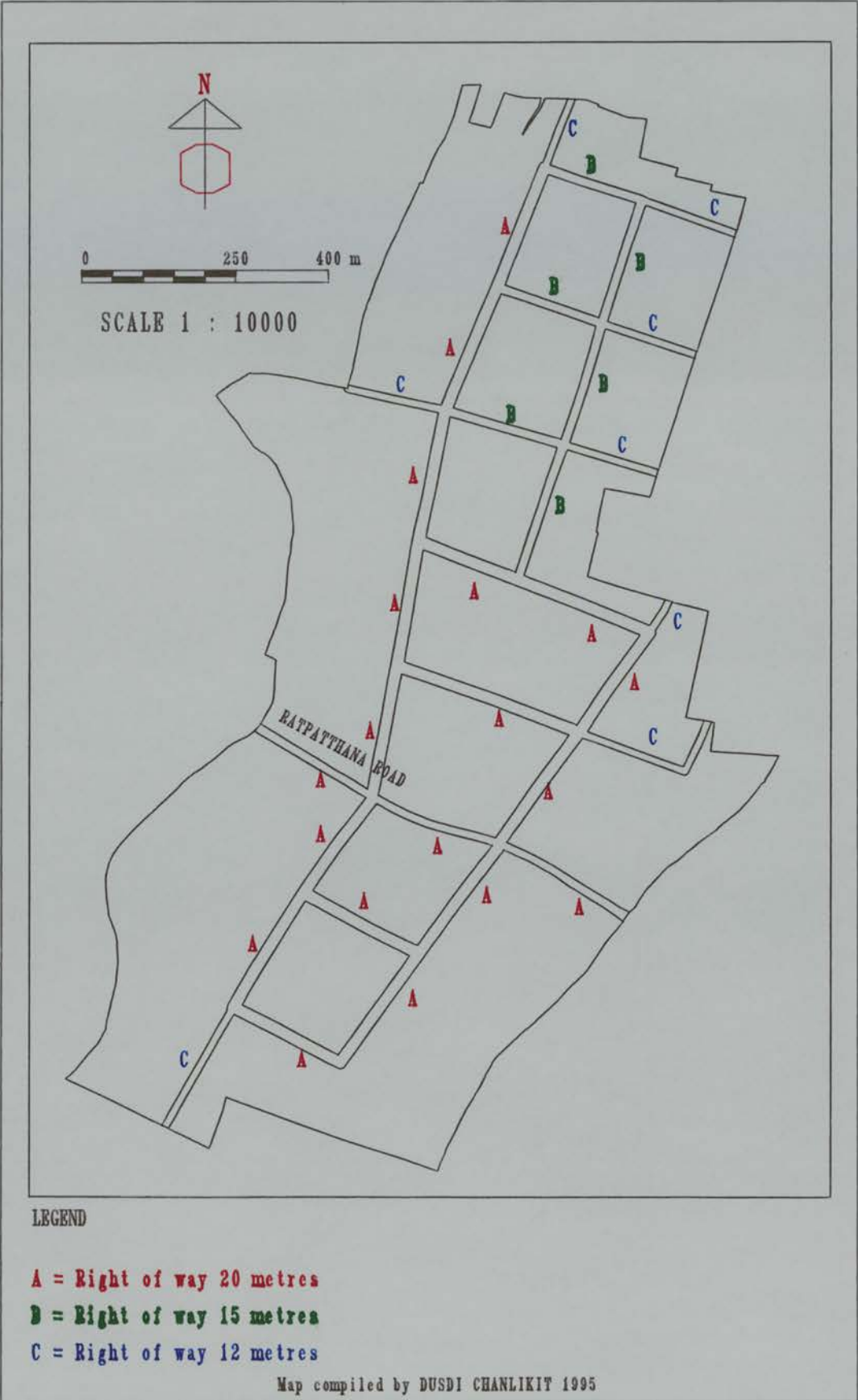


Figure 6.21 Proposed new road network in the Lad Krabang project.

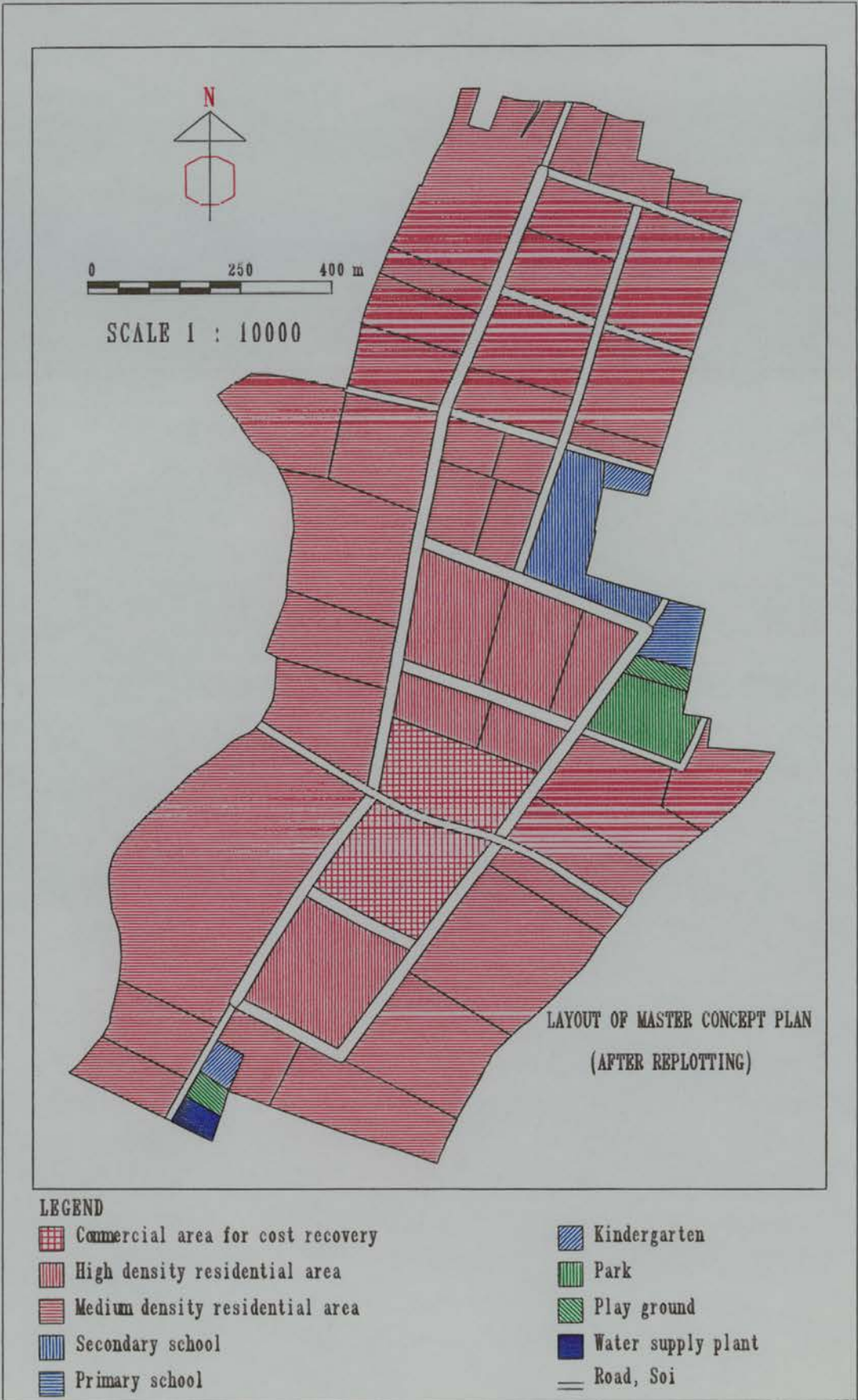


Figure 6.22 Layout of master concept plan in the Lad Krabang project.

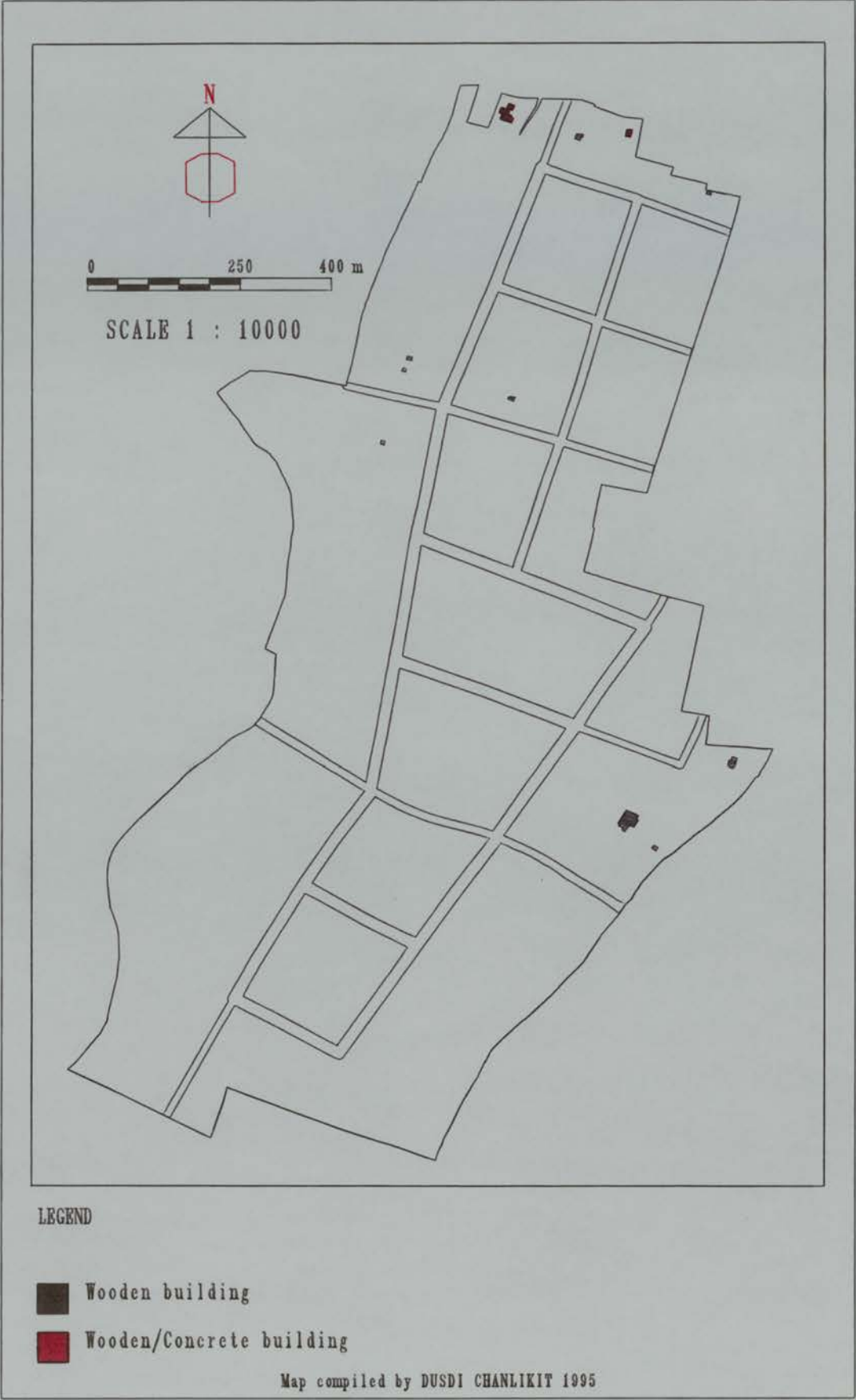


Figure 6.23 Proposed new location of buildings in the Lad Krabang project.



Figure 6.24 Location of existing trees in the Lad Krabang project.

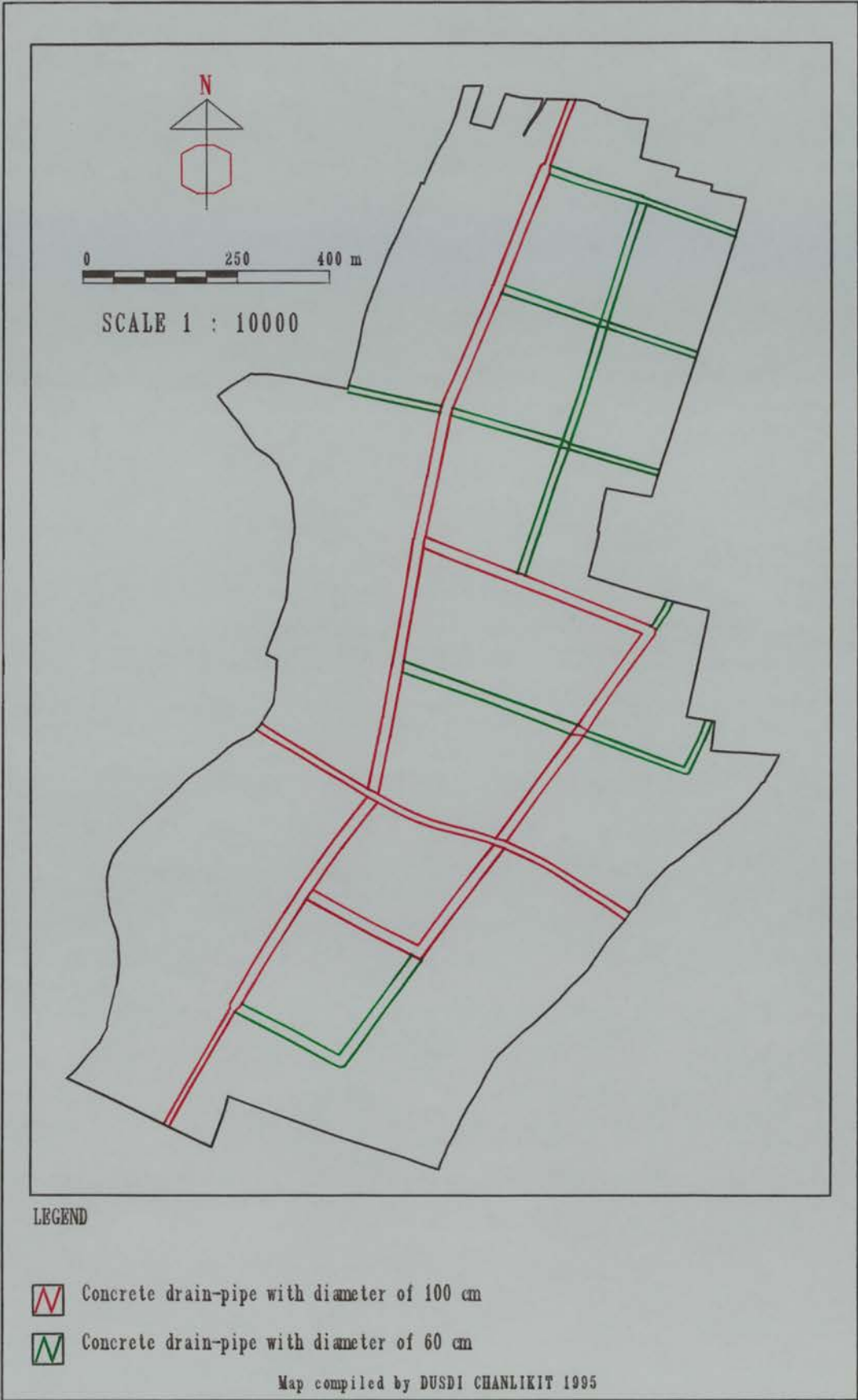


Figure 6.25 Proposed drainage system in the Lad Krabang project.

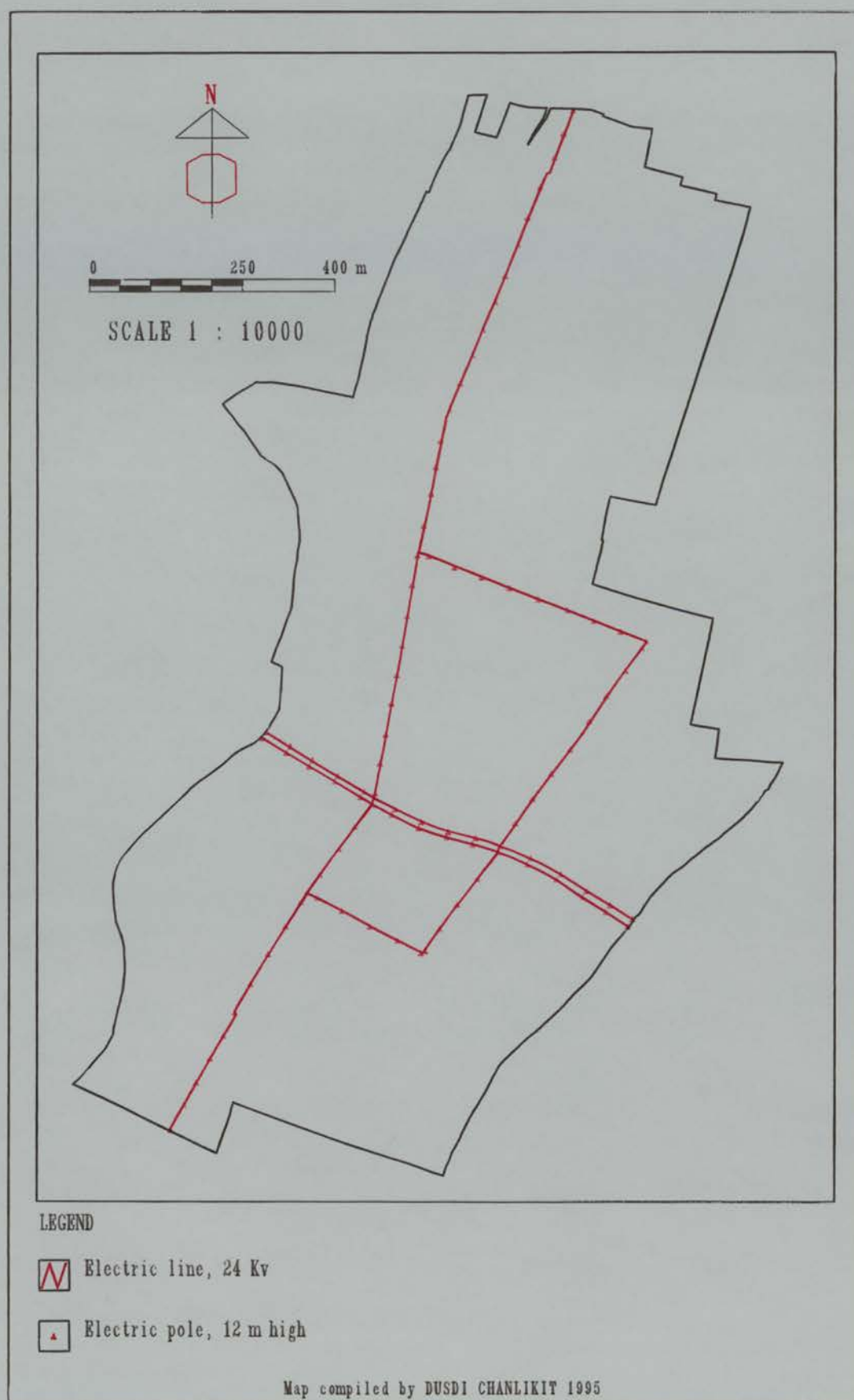


Figure 6.26 Proposed electric line and pole in the Lad Krabang project.

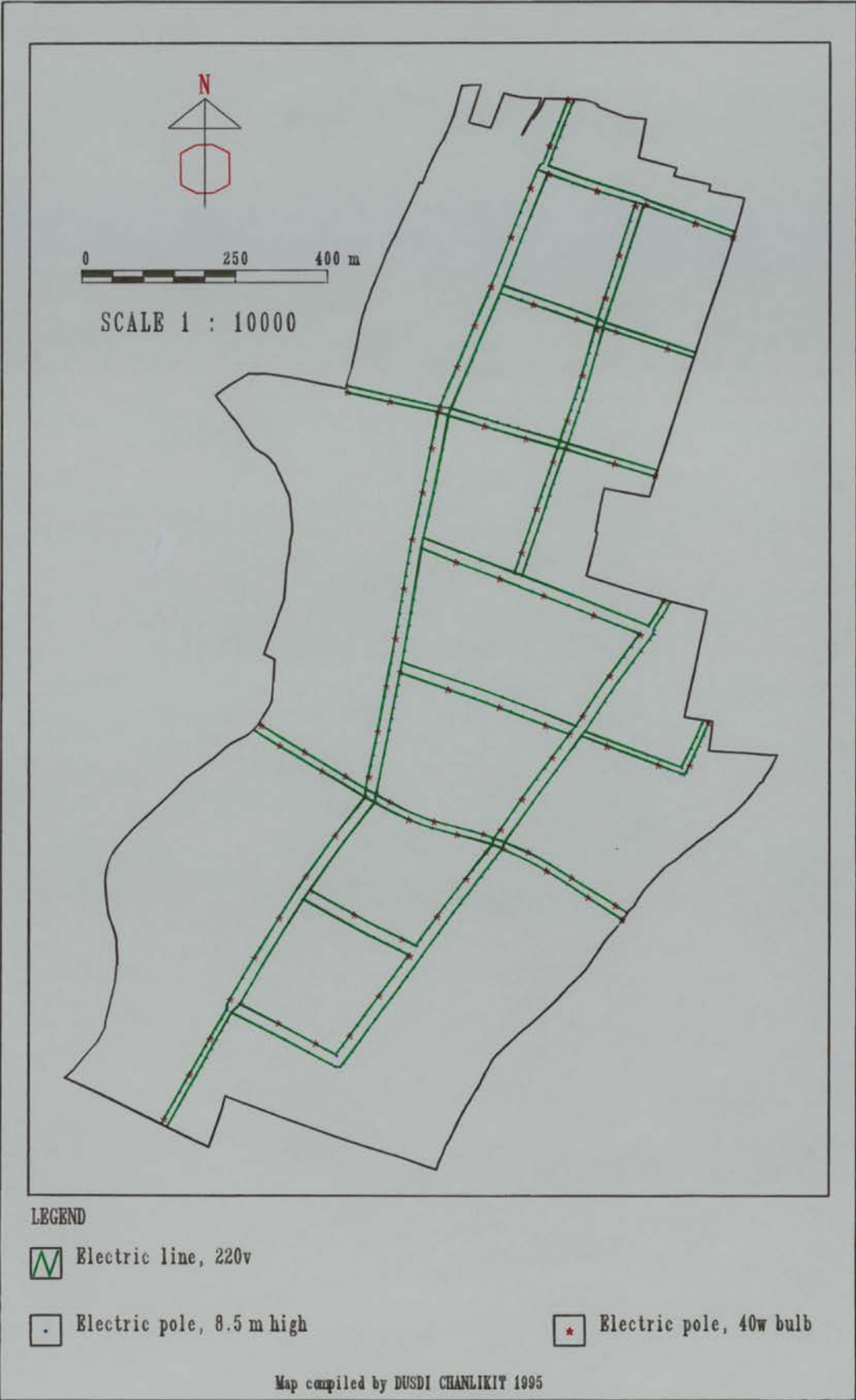


Figure 6.27 Proposed electric line, pole, and twin fluorescent bulb in the Lad Krabang project.

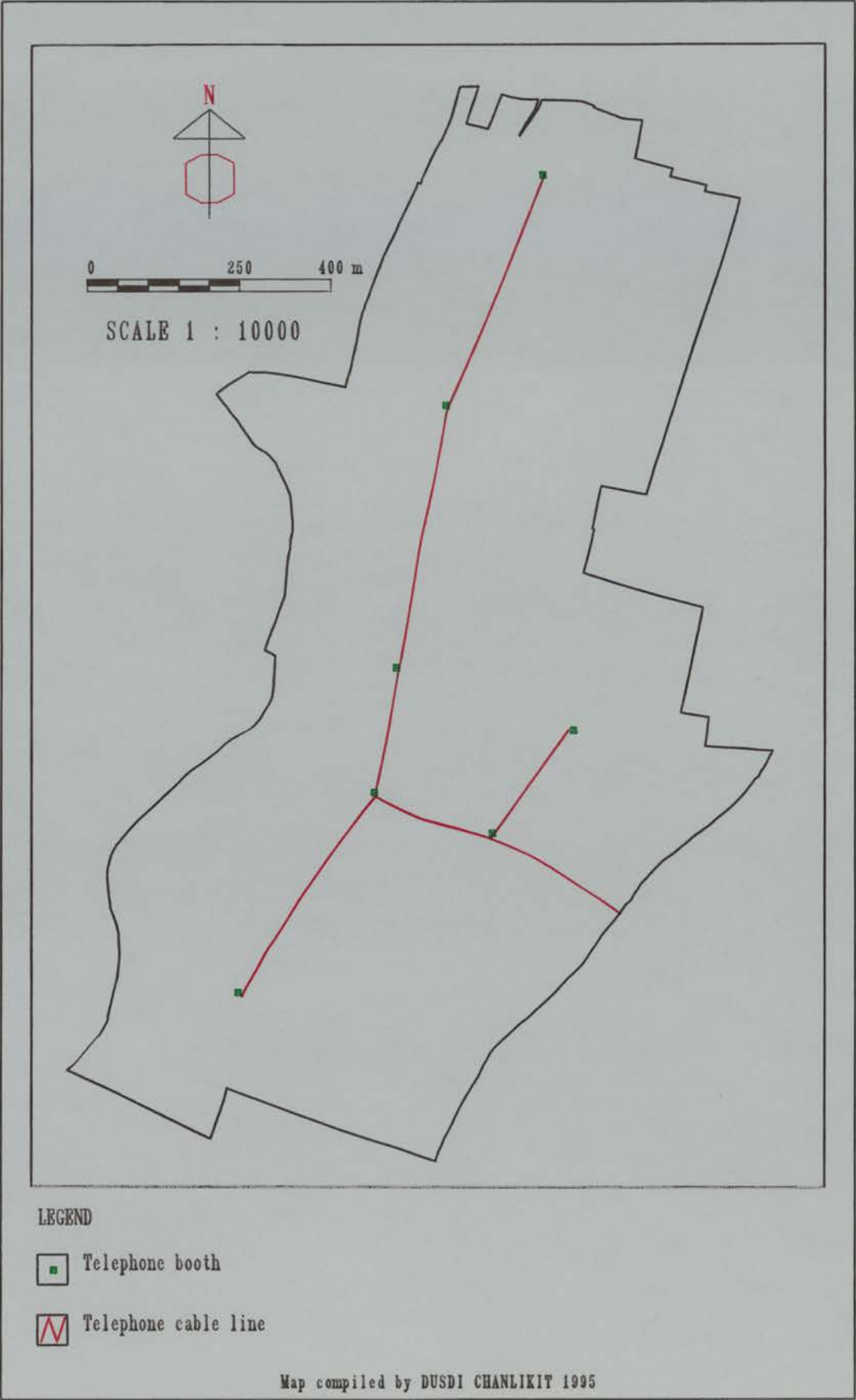


Figure 6.28 Proposed telephone booth and cable in the Lad Krabang project.



Figure 6.29 Proposed water-supply pipe and fire hydrant in the Lad Krabang project.

6) Road construction

To serve the study area effectively, a series of different road networks are provided (see Figure 6.21). The main arterial roads (20 m, with 14 m paved) are designed in the loop system in the upper part of the major road (Ratpatthana road) so as to serve the large traffic volumes which will occur in the cost recovery areas. The roads will provide good opportunity for commercial activities for the project cost. Secondary roads (15 m, with 11 m paved) are provided to connect the main arterial roads in the grid network and lastly there are 12 m collector roads (with 9 m paved) which provide access to all plots.

7) Water supply

As the site is not involved in a project to be supplied by the Metropolitan Waterworks Authority (MWA), Thailand, the underground water well has been considered to be an effective alternative. Two elevated tanks, 50 cubic metres in volume and 20 m high, will be constructed on the lowest part of the site (see Figure 6.22). From the tanks, asbestos water pipes will be laid to serve every parcel of land and fire hydrants will be placed every 250 m, as shown in Figure 6.29.

8) Control survey

Control survey is included as part of the cost of reconnaissance and involves data capture by means of GPS receivers, heighting, and field completion as already described in chapter 4, section 4.4.

9) Land title deeds

Before commencing the land readjustment process, the site consists of 27 parcels of land and the site is later replotted to 50 proposed new plots through the replotting procedure. The cost of issuing new land title deeds has to be taken into account as a portion of the project cost.

10) Landscape design and planting trees

The preservation of existing trees (eg bamboo, coconut, mango) is an important measure for the site. Also, new trees of the same or different species should be planted along both sides of roads, especially on the footpaths. In addition, amenity trees play a significant role in playgrounds and a park where landscape design is required. The cost for landscape design and planting trees is set in relation to the standard of the NHA, Thailand.

11) Administrative costs

The administrative cost of 10 per cent of the sum of the urban utility cost includes the cost of control survey, land title deed, landscape design and tree planting.

12) Interest during construction

Interest of 13 per cent is added during a half year period of construction of urban facilities. The amount of interest for the project is computed from the expenditure of urban facilities, control survey, land title deed, landscape design and planting trees, and administrative cost.

13) Contingency budget

A rate of 3 per cent is calculated from the total for installing urban utilities, control survey, issuing land title deeds, landscape design and planting trees.

In summary, compensation and infrastructure cost is calculated based on the layout plan and the standard of the MOI, MAC, MEA, TOT, and the NHA. It is obvious that the total amount of project cost is 352, 998, 909 Baht. Cost estimate for land fill, of 688.65 rai by earth fill to 1.5 metres above MSL, represents 53.24 per cent. While road construction cost is 17.03 per cent, drainage consumes 10.41 per cent of the total amount. The site is designated to provide fundamental and sufficient urban utilities and urban facilities within six months. Moreover, two large parcels adjacent

to the major road (see Figure 6.22) are chosen to be cost recovery areas and located in the commercial areas where they will contribute a good opportunity for fast sale.

6.5.3 Replotting design in the Lad Krabang project

Agricultural land use is dominant over the study area where grass and rice plantation are the main sources of income, Figure 6.30. The same criteria of replotting design described in chapter 6, section 6.4.3 also applies to the Lad Krabang project. The replotting design commences after urban utilities and urban facilities have been designed and the cost estimation of the project has been calculated. According to the Table 6.11, an area of 144.14 rai has to be provided to the project for public utility purposes. Consequently, the contribution ratio of the site is equal to 20.93 per cent of the total area (688.65 rai). Figure 6.31 shows the existing cadastral map of the site which consists of 27 plots; after introducing the urban land readjustment procedure, the site has been orientated and replotted to 50 lots with the help of the editing facility in the MULAR system. The proposed new cadastral map of the project is illustrated in Figure 6.32 where new place names and land numbers are also provided.

Table 6.11 Comparison of land use by major category in the Lad Krabang project.

LAND CATEGORY	AREA BEFORE THE PROJECT Rai	AREA AFTER THE PROJECT Rai
LAND FOR URBAN UTILITY	5.91	
Existing Ratpatthana road		
New proposed roads		62.84
Water supply plant		2.03
LAND FOR URBAN FACILITY		
Kindergarten		4.01
Primary school		5.05
Secondary school		15.54
Public park		10.4
Open space and playground		4.16
LAND FOR COST RECOVERY		40.11
	Total	144.14

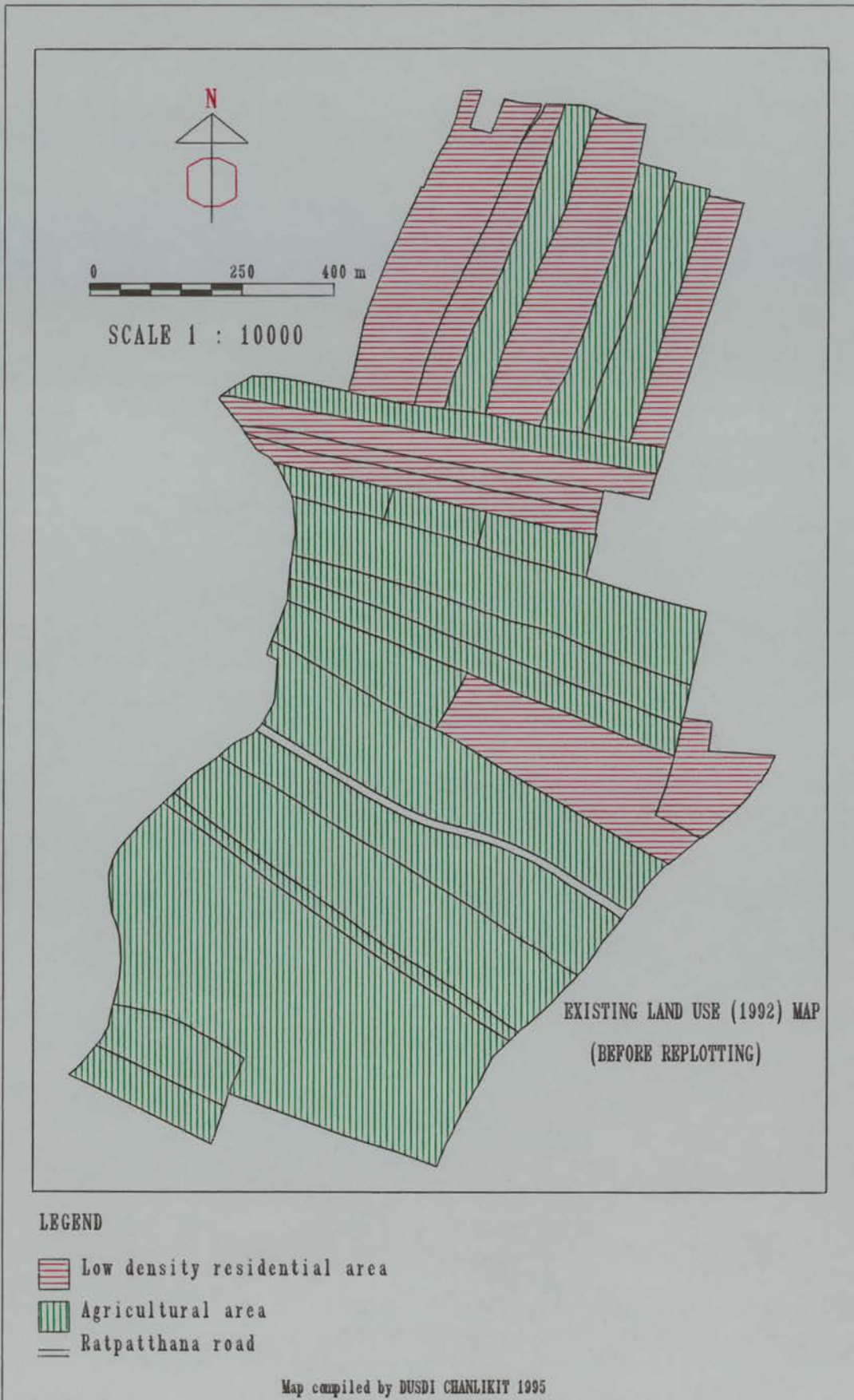


Figure 6.30 Existing land use (1992) in the Lad Krabang project.

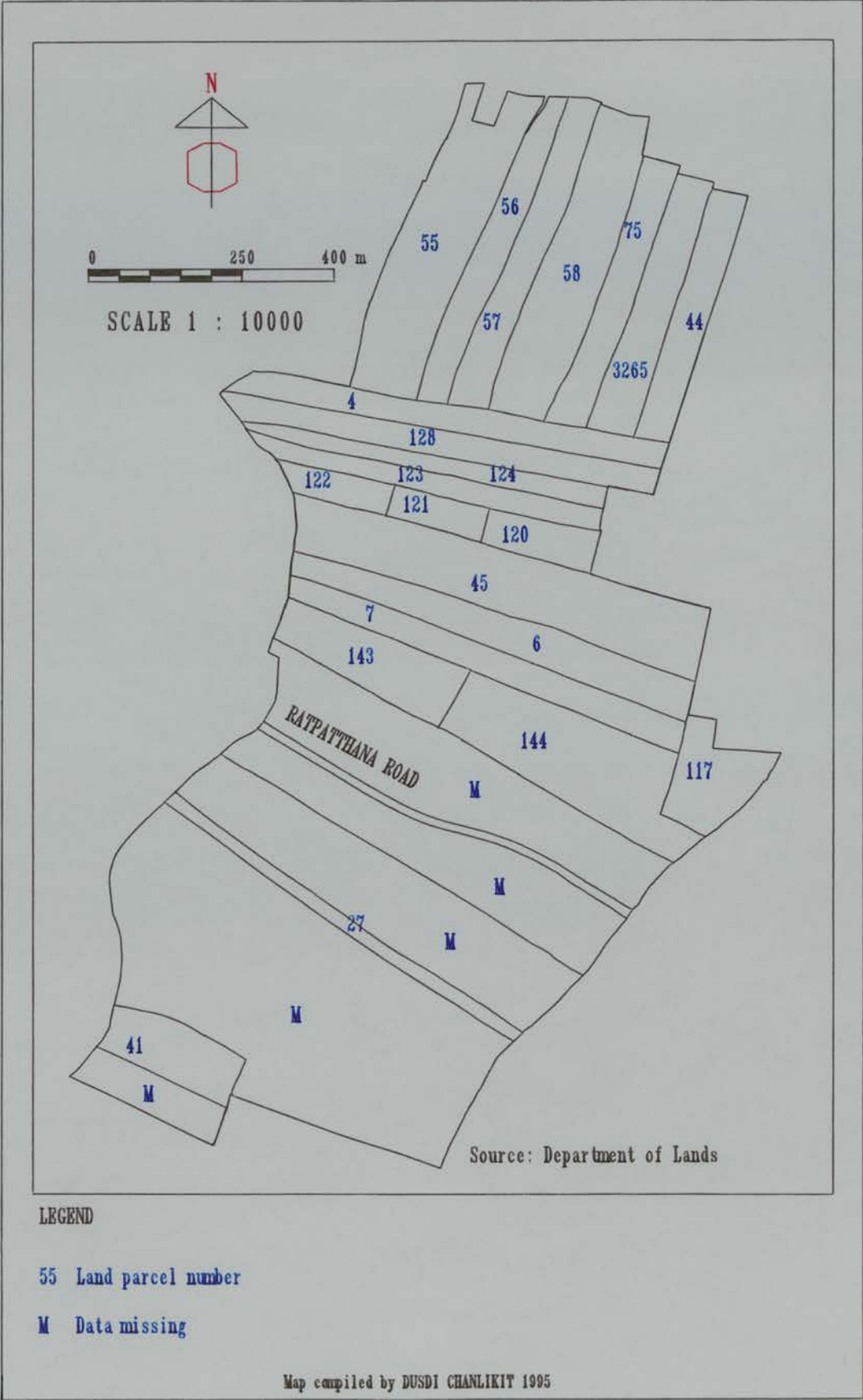


Figure 6.31 Existing cadastral map (1992) in the Lad Krabang project.

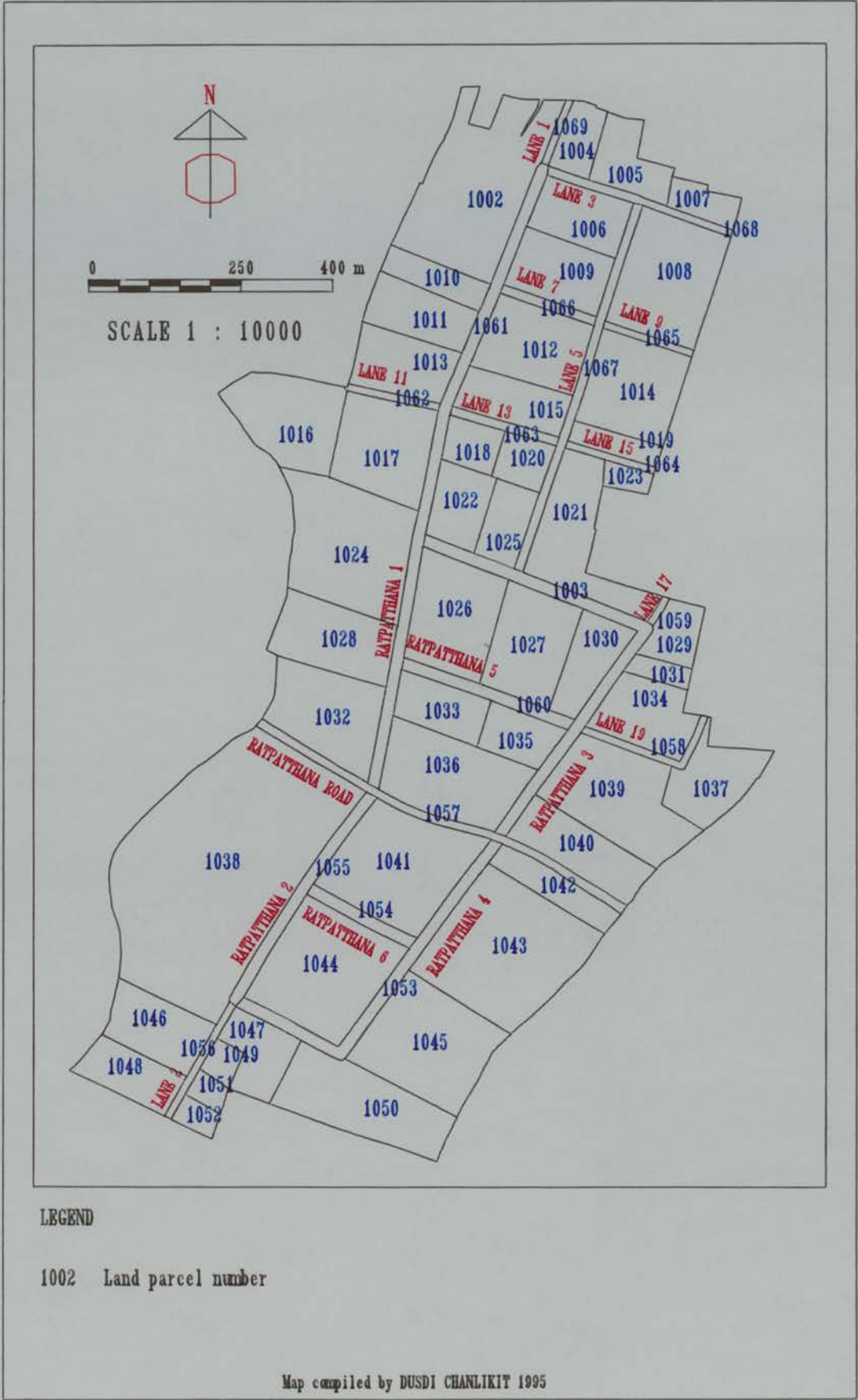


Figure 6.32 Proposed new cadastral map in the Lad Krabang project.

6.5.4 List of new parcels and valuations in the Lad Krabang project

The land value data in the Lad Krabang project was periodically collected and assessed by the DOL, for example, the increasing land value of '21 parcel' (see also Figure 6.35) was plotted and shown in Figure 6.33.

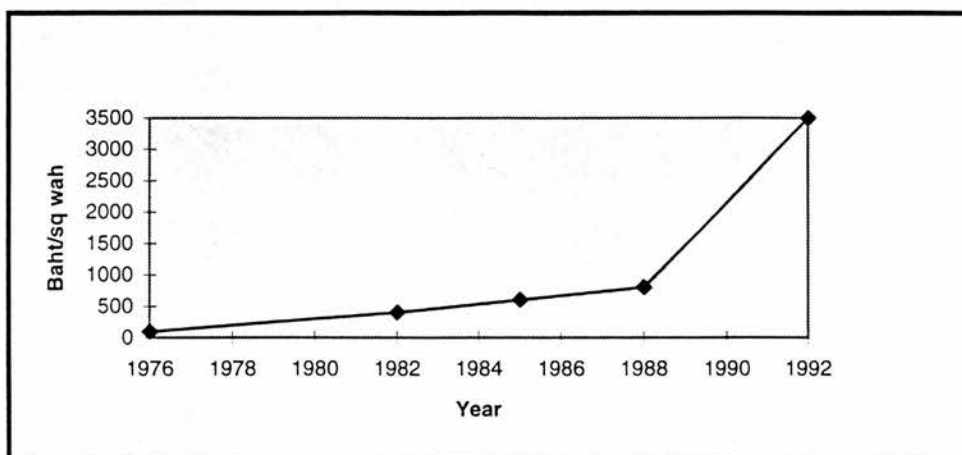


Figure 6.33 The increasing in land value of the '21 parcel' as assessed to 1992 in the Lad Krabang project.

The data have been stored in the ORACLE environment, and queried using the MULAR system. The results are presented in cartographic form in Figure 6.34. The site consists of 27 parcels of land before introducing land readjustment, Figure 6.35. Whenever land readjustment is processed, all parcels have to be reduced in size, in term of the contribution ratio, for urban utilities and urban facilities (144.14 rai); the plots are proportionally replotted into 50 new plots, Figure 6.36, with enhanced land value. In this thesis, the projected new land value is derived by using the 'market price comparison method' for which the current (1994) land value is quoted from a document released by a private housing development firm. The firm has just launched a housing project in an area which is located in the southern part of the site with the same environment. With respect to Table 6.12, the total amount of land value (assessed by the DOL in 1992) is equal to 903,960,000 Baht while the current (1994) market value of the site represents 4,757,864,000 Baht, Table 6.13. On average, the land value after the project increases by 5.26, as shown in Table 6.14. In

addition, the land areas before and after the project is given in Table 6.15. and also mapped in Figure 6.37.

In summary, the proposed master concept plan has been undertaken by using the MULAR system instead of the conventional methods. The MULAR system provides promising editing and analysing capability in land readjustment procedure, for example, adding a new line to coverage and generating buffer area for a designated polygon. Furthermore, the provision of urban utilities and urban facilities will have a great impact on reducing size of all plots but increasing in price for land value. The project revenue is derived from the sale of cost recovery lands proportionally offered by each landowner.

Table 6.12 Land values (1992) before introducing urban land readjustment in the Lad Krabang project.

Parcel number	Area Rai	Land value Baht/sq wah	Land value Baht/rai	Land value Baht/parcel
1	38.39	2,000	800,000	30,712,000
2	17.24	5,000	2,000,000	34,480,000
3	19.41	5,000	2,000,000	38,820,000
4	33.48	5,000	2,000,000	66,960,000
5	16.83	5,000	2,000,000	33,660,000
6	18.98	5,000	2,000,000	37,960,000
7	16.01	5,000	2,000,000	32,020,000
8	19.15	4,000	1,600,000	30,640,000
9	19.15	4,000	1,600,000	30,640,000
10	10.53	4,000	1,600,000	16,848,000
11	12.64	4,000	1,600,000	20,224,000
12	5.54	2,500	1,000,000	5,540,000
13	5.41	2,500	1,000,000	5,410,000
14	7.49	2,500	1,000,000	7,490,000
15	44.78	2,000	800,000	35,824,000
16	24.56	2,000	800,000	19,648,000
17	20.26	2,000	800,000	16,208,000
18	17.72	3,000	1,200,000	21,264,000
19	34.77	3,000	1,200,000	41,724,000
20	12.82	2,000	800,000	10,256,000
21	51.51	3,500	1,400,000	72,114,000
22	38.1	3,500	1,400,000	53,340,000
23	51.91	3,000	1,200,000	72,674,000
24	9.53	2,000	800,000	7,624,000
25	119.82	3,000	1,200,000	143,784,000
26	12.75	2,000	800,000	10,200,000
27	9.87	2,000	800,000	7,896,000
Total area	688.65		Total amount	903,960,000

Table 6.13 Land values (1994) after introducing urban land readjustment in the Lad Krabang project.

Parcel number	Area Rai	Land value Baht/rai	Adjusted land value Baht/parcel	Total value Baht	Land to be returned to landowner (rai)
1	30.35	8,800,000	267,080,000	267,080,000	30.35
2	4.71	8,800,000	41,448,000	119,944,000	13.63
2	8.92	8,800,000	78,496,000		
3	5.17	8,800,000	45,496,000	135,080,000	15.35
3	10.18	8,800,000	89,584,000		
4	7.17	8,800,000	63,096,000	225,216,000	26.47
4	19.3	8,400,000	162,120,000		
5	13.31	8,800,000	117,128,000	117,128,000	13.31
6	15.01	8,400,000	126,084,000	126,084,000	15.01
7	3.68	8,400,000	30,912,000	109,936,000	12.66
7	8.98	8,800,000	79,024,000		
8	15.14	8,400,000	127,176,000	127,176,000	15.14
9	15.14	8,800,000	133,232,000	133,232,000	15.14
10	8.33	8,800,000	73,304,000	73,304,000	8.33
11	9.99	8,800,000	87,912,000	87,912,000	9.99
12	4.38	8,800,000	38,544,000	38,544,000	4.38
13	4.28	8,800,000	37,664,000	37,664,000	4.28
14	5.92	8,800,000	52,096,000	52,096,000	5.92
15	3.41	8,400,000	28,644,000	310,244,000	35.41
15	7.36	8,800,000	64,768,000		
15	24.64	8,800,000	216,832,000		
16	6.08	8,800,000	53,504,000	170,896,000	19.42
16	13.34	8,800,000	117,392,000		
17	16.02	8,800,000	140,976,000	140,976,000	16.02
18	14.01	8,800,000	123,288,000	123,288,000	14.01
19	7.74	8,800,000	68,112,000	241,912,000	27.49
19	19.75	8,800,000	173,800,000		
20	10.14	8,400,000	85,176,000	85,176,000	10.14
21	6.22	8,800,000	54,736,000	358,424,000	40.73
21	11.34	8,800,000	99,792,000		
21	7.52	8,800,000	66,176,000		
21	15.65	8,800,000	137,720,000		
22	30.13	8,800,000	265,144,000	265,144,000	30.13
23	18.18	8,800,000	159,984,000	361,152,000	41.04
23	22.86	8,800,000	201,168,000		
24	7.54	8,800,000	66,352,000	66,352,000	7.54
25	22.27	8,800,000	195,976,000	833,712,000	94.74
25	72.47	8,800,000	637,736,000		
26	10.08	8,400,000	84,672,000	84,672,000	10.08
27	7.8	8,400,000	65,520,000	65,520,000	7.8
Total				4,757,864,000	544.51

Table 6.14 Land values after introducing urban land readjustment in the Lad Krabang project.

Parcel number	Land value (Before) Baht/parcel (* 1000)	Land value (After) Baht/parcel (* 1000)	Increased land value Baht/parcel (* 1000)	Multiplied
1	30,712	267,080	236,368	8.7
2	34,480	119,944	85,464	3.48
3	38,820	135,080	96,260	3.48
4	66,960	225,216	158,256	3.36
5	33,660	117,128	83,468	3.48
6	37,960	126,084	88,124	3.32
7	32,020	109,936	77,916	3.43
8	30,640	127,176	96,536	4.15
9	30,640	133,232	102,592	4.35
10	16,848	73,304	56,456	4.35
11	20,224	87,912	67,688	4.35
12	5,540	38,544	33,004	6.96
13	5,410	37,664	32,254	6.96
14	7,490	52,096	44,606	6.96
15	35,824	310,244	274,420	8.66
16	19,648	170,896	151,248	8.7
17	16,208	140,976	124,768	8.7
18	21,264	123,288	102,024	5.8
19	41,724	241,912	200,188	5.8
20	10,256	85,176	74,920	8.3
21	72,114	358,424	286,310	4.79
22	53,340	265,144	211,804	4.97
23	72,674	361,152	288,478	4.97
24	7,624	66,352	58,728	8.7
25	143,784	833,712	689,928	5.8
26	10,200	84,672	74,472	8.3
27	7,896	65,520	57,624	8.3
Total	903,960	4,757,864	3,853,904	5.26

Table 6.15 The size of land before and after introducing urban land readjustment in the Lad Krabang project.

Parcel number	Area (Before) Rai	Area (After) Rai
1	38.39	30.35
2	17.24	13.63
3	19.41	15.35
4	33.48	26.47
5	16.83	13.31
6	18.98	15.01
7	16.01	12.66
8	19.15	15.14
9	19.15	15.14
10	10.53	8.33
11	12.64	9.99
12	5.54	4.38
13	5.41	4.28
14	7.49	5.92
15	44.78	35.41
16	24.56	19.42
17	20.26	16.02
18	17.72	14.01
19	34.77	27.49
20	12.82	10.14
21	51.51	40.73
22	38.1	30.13
23	51.91	41.04
24	9.53	7.54
25	119.82	94.74
26	12.75	10.08
27	9.87	7.8
Total	688.65	544.51

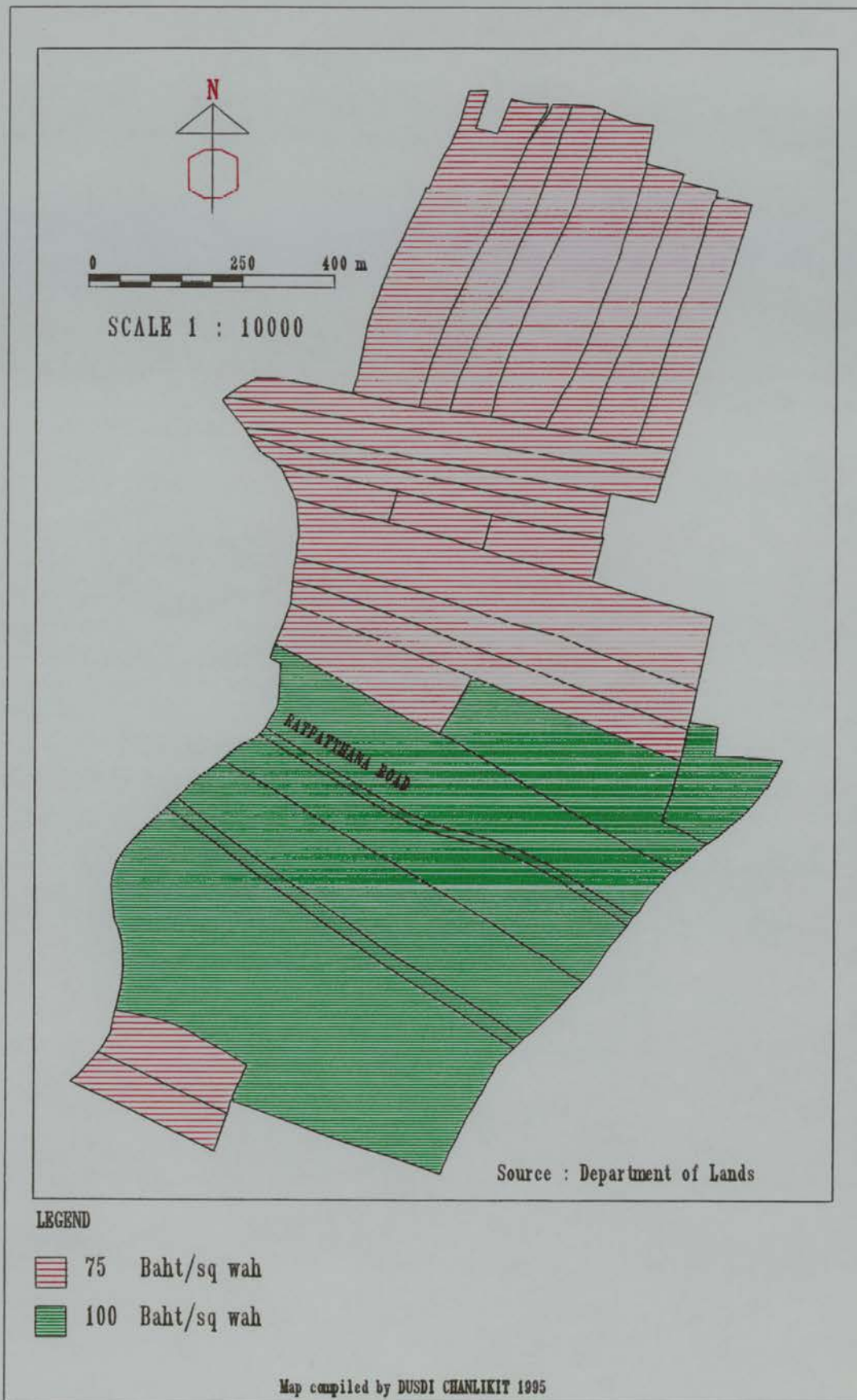


Figure 6.34 Land value map for 1976 in the Lad Krabang project.

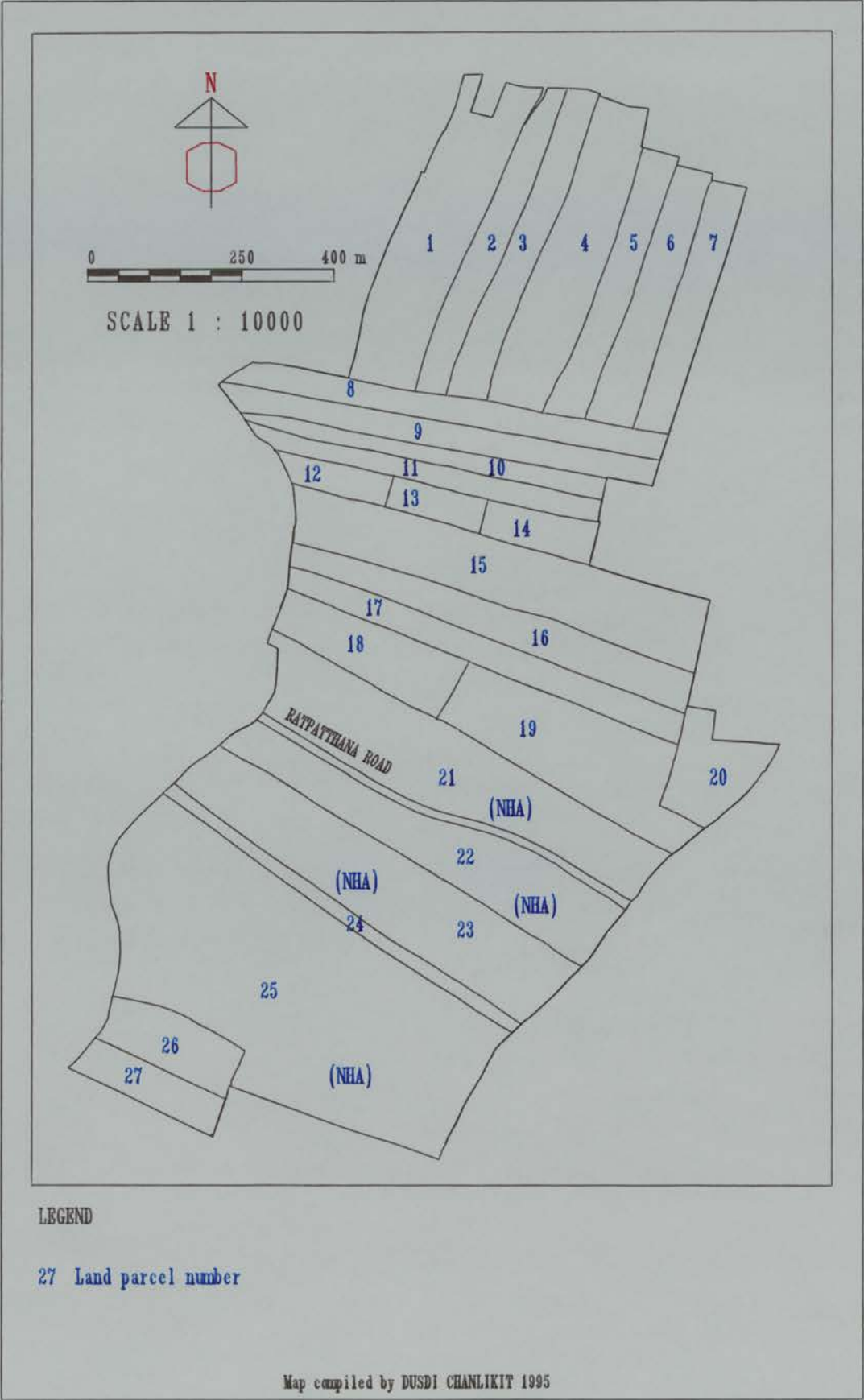


Figure 6.35 Numbering of land parcels before replotting procedure.

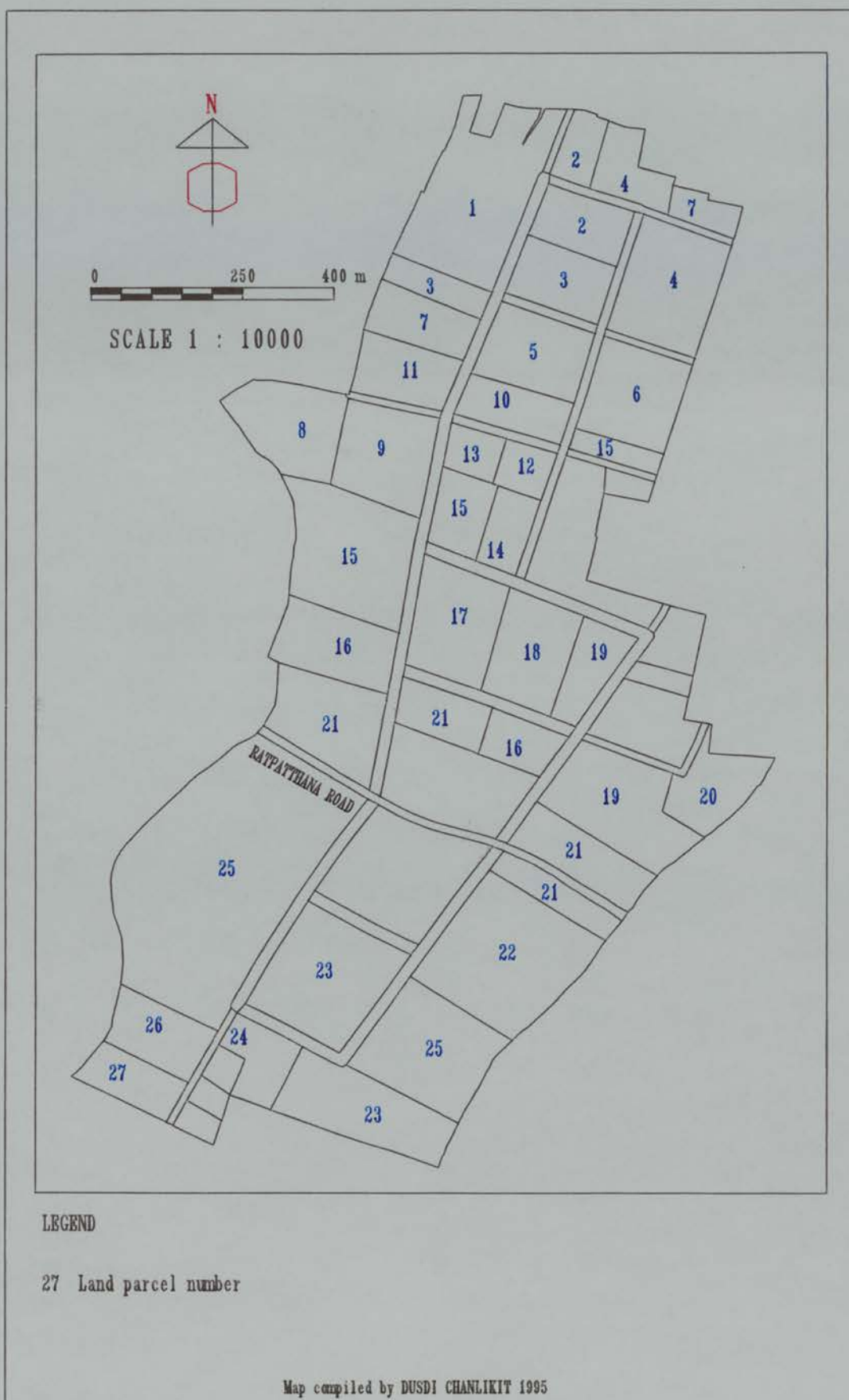


Figure 6.36 Numbering of land parcels after replotting procedure.

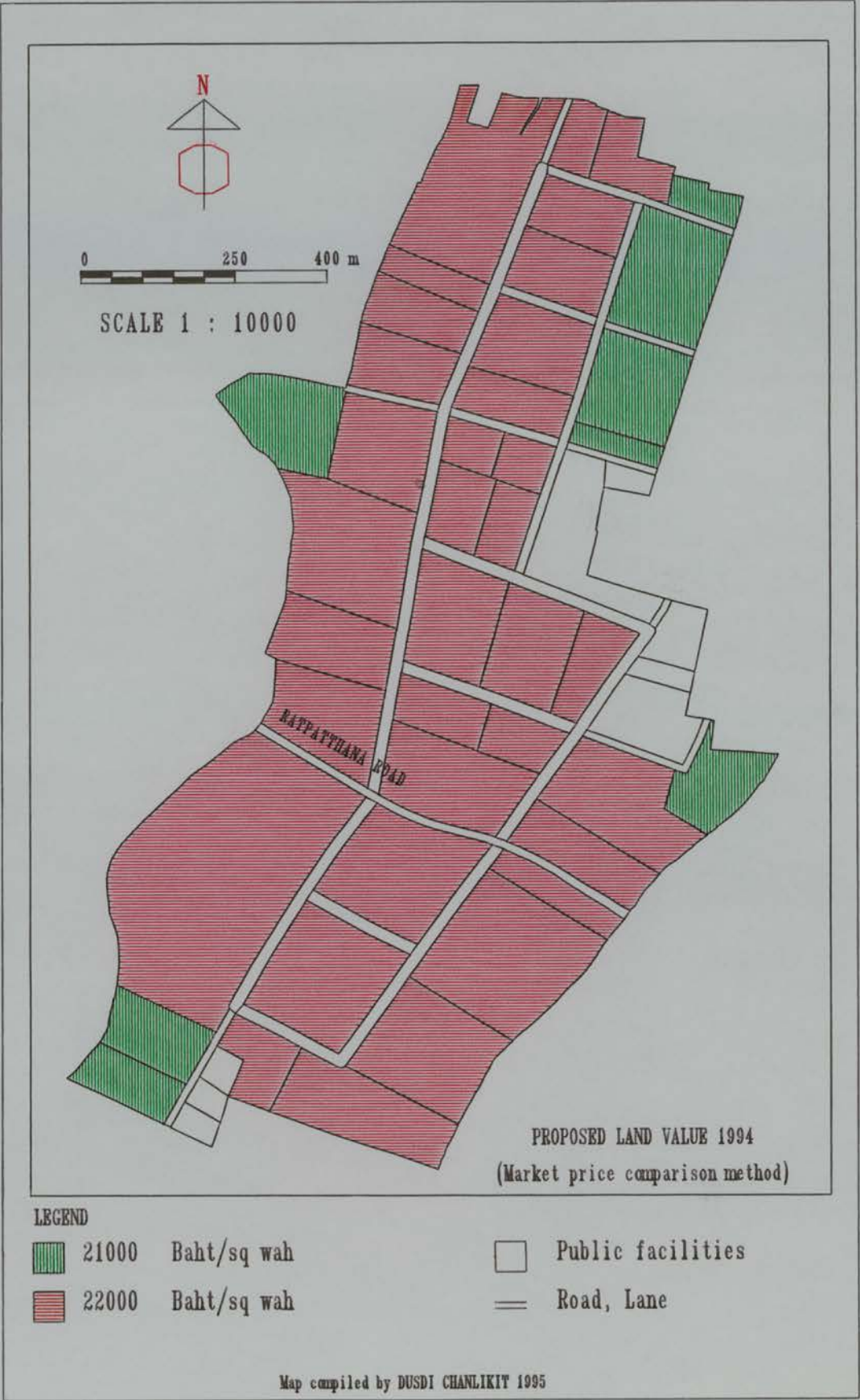


Figure 6.37 Proposed land value after replotting in the Lad Krabang project.

6.6 CONCLUSIONS

The pre-feasibility study of urban land readjustment in the Lad Krabang project has been reported by the NHA since 1992 as already described in chapter 2, section 2.9.2. The study area in the Lad Krabang project presented in the thesis is exactly the same area as the NHA has been studied, but the approach is different. Generally speaking, the traditional methods used by the NHA in conducting land readjustment are considered to be time consuming and duplicative, leading to the registration of inaccurate data, while the LIS/GIS technological approaches introduced by the author are regarded as more acceptable. A comparison of methodology for undertaking urban land readjustment presented by the NHA and the author is shown in Table 6.16.

In the newer technological approach, it is evident that the global positioning system (GPS) is a crucial tool for yielding accurate coordinates for the aerial triangulation process and for local positioning while the AP190 analytical stereoscopic plotter is not difficult to operate and requires less effort than traditional field survey method. The ORACLE package provides flexibility for coordinate and attribute data storage, updating and retrieving. In addition, the ARC/INFO/TIN softwares, AML programming, and the created MULAR system play a substantial role for urban land readjustment analysis and for yielding various forms of graphic output. In summary, it is suggested that these techniques could be adopted in large-scale urban mapping as a practical model for urban land readjustment in Thailand and other developing countries.

Table 6.16 A comparison of methodology between the NHA and the author for undertaking urban land readjustment in the Lad Krabang project.

PROCEDURE	NHA APPROACH	AUTHOR'S APPROACH
GRAPHIC DATA CAPTURE		
Utilisation of existing maps	Yes	Yes
Utilisation of aerial photographs	Yes (general purposes)	Yes (designing of photo control points)
Control survey with a level and GPS receivers	No	Yes
Aerial triangulation	No	Yes (BLOKK package)
Digital mapping using a stereodigitising instrument	No	Yes (AP190 analytical stereoplotter)
Perspective and panoramic viewing	No	Yes (ARC/TIN)
DATABASE MANAGEMENT SYSTEM		
Relational database management system	Yes (dBASE III Plus)	Yes (ORACLE)
Relationship between graphic and non-graphic data	No	Yes (ARC/INFO relates ORACLE)
LAYOUT OF MASTER CONCEPT PLAN		
Master concept design	Yes (conventional)	Yes (MULAR system)
Urban facility design	Yes (NHA standard)	Yes (NHA standard)
COST ESTIMATION		
Compensation cost of buildings and trees	No	Yes (MOI, MAC standard)
Public telephone cost	No	Yes (TOT standard)
Land fill estimation	Yes (conventional)	Yes (AP190 and the written program)
Other public utilities costs	Yes (NHA standard)	Yes (NHA, MEA, MWA standard)
REPLOTTING PROCESS		
Replotting design of new plots	Yes (traditional)	Yes (MULAR system)
LIST OF NEW PLOTS AND VALUATIONS		
List of new plots	Yes (dBASE III Plus)	Yes (ORACLE)
List of new valuation of plots	Yes (dBASE III Plus)	Yes (ORACLE)
Graphic output of new plots	Yes (traditional)	Yes (MULAR system)

Chapter 7

CONCLUSIONS AND FURTHER RESEARCH

7.1 INTRODUCTION

This chapter includes four distinct activities. The first is to synthesise the principal findings and conclusions presented in chapters 2 to 6 with regard to the recent study. The second is to describe how the proposed strategy has advantages over the existing practice while in the third part details of research contributions are reviewed. The last is to describe how the MULAR system might be modified for operational use or tested further in other areas.

7.2 SUMMARY OF PRINCIPAL FINDINGS AND CONCLUSIONS

Significant developments have occurred in the study of land readjustment in the four years since the present study was initially conceived. Many of these developments provide additional support for the validity and utility of the present study. Interest in urban land readjustment has been revitalised as researchers, politicians, government agencies, and the public have increasingly recognised the importance of urban land readjustment as having an impact on the management of urban growth. This has been evident in shifts in government policy from previous interest for the Bangkok Metropolitan area to the present focus also on other provincial municipal areas. The use of urban land readjustment was eventually recommended by the Office of National Economic and Social Development Board (NESDB) to be a vital tool for both private and government sectors for supporting the Seventh National Social and Economic Development Plan (1992 - 1996), as described by the NESDB (1994).

The approach applied in this thesis is general in nature. The author has made no attempt to justify the implementation of the application of a LIS/GIS technology for urban land readjustment through a cost benefit analysis. The basic philosophy of this thesis has been to investigate the problems associated with a strategy of utilising the LIS/GIS techniques for monitoring and enhancing traditional land readjustment processes in the Thai environment. The significant findings of the present study leads to the following conclusions and results:

1. Even though land readjustment has been undertaken and has succeeded in many parts of the world, it is a relatively new concept among Thai city planners. However since 1988 the Thai agencies have conducted many studies on land readjustment; for example, the DTCP undertook pilot studies in Chon Buri province, in Bangkok, and in Lop Buri province while the NHA conducted a feasibility study of the suburban environment in Bangkok. A large-scale base map (eg cadastral map) has been involved in the NHA land readjustment procedure and city planners have utilised it in the process of layout of the master concept plan and replotting of new plots. The author finds that the existing urban and suburban cadastral maps, produced by the DOL, are incomplete, out of date, or at too small a scale for city planners to generate the proper urban land readjustment. The rudimentary cause of the current problem means that cadastral maps cannot be updated fast enough to keep pace with the rapid urban growth rate; these maps are deemed to be crucial tools for city planners whenever urban land readjustment is carried out. The problem is clearly seen in the Bangkok Metropolis where access to fundamental land ownership and land parcel information is made more difficult because of the lack of basic cadastral index maps, such as large-scale maps for building and vegetation types. The lack of up-to-date and good quality urban cadastral maps has created problems for authorities dealing with land management, planning and provision of new public facilities. In many cases, different government bodies and utilities agencies have attempted to produce their own urban maps to help meet their specific requirements. As a result, there has

been duplication of work and the accuracy of the original maps cannot be maintained.

2. Manual techniques of map analysis, like using a planimeter for measurement of specific areas and/or using a scale ruler for measuring the length of a proposed urban utility network, are still applied among city planners. These techniques are considered to be completely labour intensive, inaccurate and time consuming. By doing so, the cost estimation of proposed public facilities is bound to achieve inaccurate results.
3. The current land readjustment process lacks good database management systems (DBMS) for non-graphic or attribute data, causing unreliable or wrong results. The process of cost estimation for financial plan is also depended on reliable DBMS. Moreover, by the current manual procedure there is no linkage between graphic and non-graphic data; therefore, efficient spatial analysis for urban land readjustment is impossible.
4. The author provides the solutions to investigate the practicality and suitability of using LIS/GIS techniques - for example, introducing surveying and photogrammetric approaches, a relational database management system (RDBMS), a model for urban land readjustment (MULAR) system - to cope with the current problems of undertaking urban land readjustment. The following significant steps are required for this proposed new method for handling the urban land readjustment.
 - acquisition of existing maps and aerial photographs;
 - site selection and boundary;
 - preparation for field work;
 - reconnaissance and field identification;
 - mensuration by GPS;
 - heighting;

- aerial triangulation;
- digital mapping;
- field completion;
- classification of land use, building type, and vegetation cover type;
- database design;
- layout of master concept plan;
- cost estimation;
- replotting design and plan;
- list of new parcels and valuations.

The proposed strategy for urban land readjustment mentioned above involves data acquisition, data capturing, data analysis by using the MULAR, and output of various forms of graphic and non-graphic data. The surveying and photogrammetric techniques have been executed to provide reliable and accurate graphic data while the RDBMS yield a consistent quality and integrity of non-graphic data. By means of GIS packages, graphic data, non-graphic data, and programming languages play a tremendous role in achieving an efficient spatial analysis for monitoring urban land readjustment.

5. There is a wide variety of global positioning systems (GPS) available in current use, any of which could be used for land readjustment work. In this case, a set of three identical Trimble 4000ST GPS receivers have been used to provide planimetric coordinates, while vertical positioning accuracy has been accomplished by means of levelling using a WILD NK2 level for urban mapping in the Lad Krabang project. The control coordinates have been utilised for achieving minor control points and for generating a digital terrain model.
6. The potential for photogrammetry in LIS/GIS is quite evident (Warner *et al.*, 1991). Much of the information from photographs is now required in digital form, which is achieved using computer-driven analytical instruments (Kirby, 1990). After the orientations are properly performed, a stereoscopic model is digitised

directly to produce accurate and reliable maps (eg cadastral map, building type map). Even for engineering purposes it is standard procedure to use photogrammetry for topographic mapping at scales as large as 1: 500 (Dale, 1976). It is evident that photogrammetry is the first and most fundamental process of data collection in many GIS systems. In this research, the full ground control points obtained by the Trimble 4000ST GPS receivers and by levelling were applied in an independent model block adjustment program, embedded in the AP190 analytical stereoplotter environment, which provides a number of minor control points. All of the minor control points were obtained by using an aerial triangulation procedure which is considered to be a cost-efficient method for providing reliable ground control points for orientating stereomodels. It is also more economic in terms of budget, time, and manpower than the traditional ground surveying method. Following this, the stereoplotter has been utilised for collecting digital data from each stereoscopic model directly - the data have been later converted to the LIS/GIS environments.

7. A number of independent model blocks were observed by means of the AP190 analytical stereoscopic plotter using four different sets of ground control points. It was apparent that sigma naught values of the block of SET 4 (comprising 5 full ground, 11 vertical ground and 12 additional vertical control points) provided a more rigorous result than the three remaining blocks. Consequently the result of the SET 4 was considered as being most outstanding as the design for a control point file.
8. With the help of a flatbed digitiser (Summagraphics 'MICROGRID'), the locations of existing telephone booths, fire hydrants, letter boxes, and electric poles derived by a field completion - in the Klong Toei and the Lad Krabang project - were digitised and transferred to the GIS package (ARC/INFO) for analysing and producing various types of digital maps.

9. The ORACLE package, a relational data base management system, has been used as an external hybrid DBMS software for the proposed MULAR system both in the Klong Toei and the Lad Krabang project because the package provides high 'data integrity' which is deemed to play a significant role in monitoring non-graphic data for the LIS/GIS. Graphic and non-graphic data have been loaded using an interactive application processor (IAP), ORACLE SQL*Forms version 3.0, which is a screen data entry. The IAP has many functions to assist with screen handling and data entry that can be used with a wide variety of CRT terminals. It can also be handled to enter data, retrieve data, and modify data in an ORACLE database. The ORACLE package has been selected to support promising solutions to cope with the LIS/GIS data and it can be used in two distinct ways: interactive or embedded structured query language (SQL). Using SQL interactively, involved straightforward answers and a simple query language while with embedded SQL, statements are normally included in a program that has been written in another programming language. In order to write a program that accesses the ORACLE database, the author began with a conventional programming language, such as C or FORTRAN and then added the SQL statements. Moreover, the SQL embedded in a host program has a significant effect in optimising the processing of the SQL statement.

10. The MULAR system has been written using the Arc Macro Language (AML) and has been designed as a 'hierarchical' structure, which will require only a little customisation to incorporate the user specific data model. The system has been divided into six main menu bars: EDITING, ANALYSIS, QUERY, DISPLAY, PRINTOUT, and HELP in order to allow any user to utilise it to create, analyse, and retrieve data of their own requirements. It has also been designed by means of a pulldown menu which is invoked using the &MENU directive. The fundamental design of the MULAR system for the two study areas is quite similar in definition and function to the 'choice menu' except that in the suburban area the user has more choices for urban facility analysis than in the urban area. From an academic

perspective, the system is finally proved, to a greater or lesser extent, to be an important tool for city planners to conduct urban land readjustment effectively and the system has also potential for future expansion as required.

Figure 7.1 illustrates the proposed structure of the LIS and MULAR system for monitoring urban land readjustment. The structure consists of three principal procedures: data input, processing, and data output. Graphic and non-graphic data were collected by means of field work in Bangkok Metropolis. The graphic data were processed and converted to digital forms using a photogrammetric approach while the non-graphic data were loaded into a RDBMS environment and utilised for land value and cost estimation analysis. With the help of the MULAR system, the digital data were retrieved and processed to produce different kinds of maps.

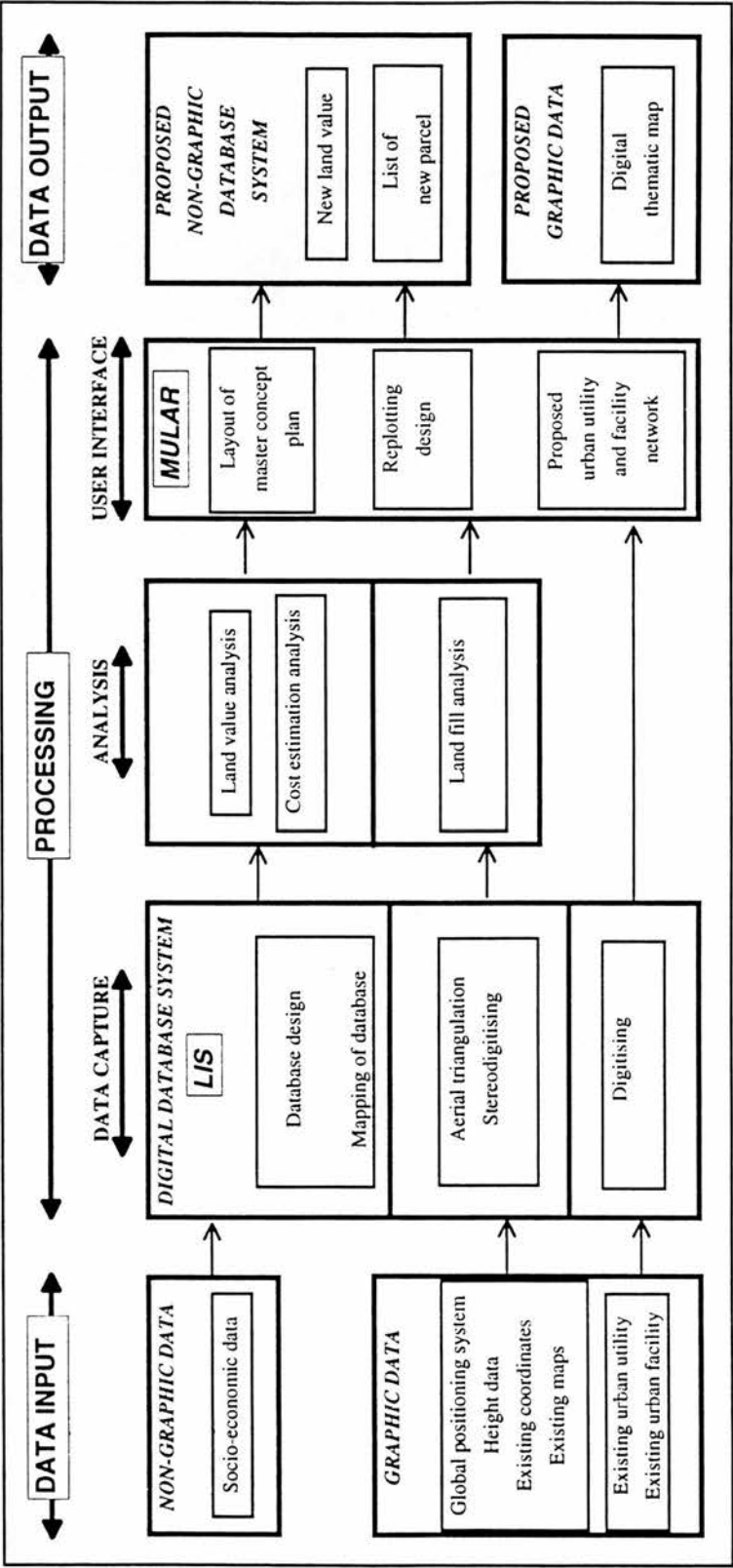


Figure 7.1 The proposed structure of LIS and MULAR system for urban land readjustment in Thailand.

7.3 THE ADVANTAGES OF THE PROPOSED STRATEGY OVER THE EXISTING PRACTICE

Urban land readjustment has been studied by a number of Thai government agencies since 1988, but many of these agencies are using traditional methods which are considered to be tiresome, inaccurate, and time consuming. It is the aim of this thesis to suggest how urban land readjustment can be undertaken efficiently using the modern technologies (eg GPS, and photogrammetry) which are considered to be more flexible, accurate, and consistent than the conventional approaches. The outstanding advantages of applying the LIS technology can be summarised as follows:

1. The cadastral map derived by means of surveying (eg GPS) and photogrammetric approaches (eg independent model block adjustment, stereodigitising) yields more reliable and accurate results than the existing map produced by the DOL. As an example, compare Figure 6.31 and 3.2. In addition, the proposed approaches provide greater flexibility; therefore they can also be applied for objectives where the existing cadastral map is not available.
2. Once the graphic data are converted into digital form, the digital data can be easily transferred to other CAD or LIS/GIS systems and the data can also be plotted at any specified scale as required without any loss of accuracy.
3. A GIS package such as ARC/TIN provides panoramic viewing and spatial analysis of related data (eg land use, building type, vegetation type) which can be easily overlaid on the three dimensional surface (see Figure 6.2).
4. The attribute data related to land (eg land parcel number, address of landowner, land value) have been loaded into the ORACLE package where it has the significant advantage that its structure is simple, in that all the data are represented

in tables of rows and columns. It also permits different sorts of data to be updated, retrieved, combined, and compared. Beyond that, the connection between graphic and non-graphic (attribute) data is made possible. As a result, city planner can simultaneously access data stored in the ORACLE environment by using database integrator modules provided by the ARC/INFO. By doing so, the graphic data have been kept in the ARC/INFO while the non-graphic data have been loaded in the ORACLE environment; therefore the processing time for graphic analysis is relatively less than by loading the non-graphic data into the INFO.

5. One of the great advantages of the MULAR system is that it can integrate a number of different software packages (eg ARC/INFO/TIN, ORACLE) by using the capability of the AML. The system is written using modular programming to cope with complex applications. For example, the system provides editing facility to edit a target coverage which can be line, point or polygon in ARCEDIT environment. Therefore, tedious and difficult graphic tasks such as layout of master concept plan and replotting design of new plots can be accomplished by the editing facility embedded in the MULAR system. It also permits a designated coverage to be used as a background display while a target coverage is being edited. With the help of the AML, spatial analysis such as buffering lines/points/polygons, and retrieving data from the ORACLE for shading designated polygons can be repeated and performed interactively in the ARC/INFO/ARC PLOT environment between computer and city planner.

In summary, the proposed strategy provides promising capabilities for data capturing, editing and analysing in urban land readjustment procedures. The strategy is far more accurate, consistent, flexible, and acceptable than the current traditional practice.

7.4 RESEARCH CONTRIBUTIONS

In the research, three identical GPS receivers, a surveying level, an AP190 analytical stereoscopic plotter, and a flatbed digitiser have been used in data capturing for the LIS/GIS community. The third generation programming languages such as C, FORTRAN, PASCAL and fourth generation programming languages (eg SQL, AML) have been used in several areas. These programming languages have been written to support several operations: servicing as a host language in the RDBMS; computing of mask angle for GPS setting, which were involved in the process of producing a DTM in ARC/TIN; and computing of earthwork design in the urban land readjustment process. In addition, the AML has been developed in order to enhance the MULAR system. These written programs and the created MULAR system will be of significant benefits to city planners in a number of ways. Figure 7.1 shows the proposed structure of the LIS techniques and the created MULAR system which has been used for the urban land readjustment process. The LIS techniques play a vital role in the data capturing process. Pre-existing and newly-written programs can perform mathematical analysis while the MULAR system can execute spatial analysis and produce graphic output with a wide range of maps.

7.5 FURTHER RESEARCH

A valid concern with the study previously described is how the proposed procedures and models might be best applied/modified for operational use. There are several minor and feasible modifications that would make the procedures more effective for further research. These are now outlined.

- Develop and implement the MULAR system further, using the user specific data model.
- Develop user specific data models for other MULAR system users.

- Produce a common and formal user requirements specification for the MULAR system implementation using this thesis as a basis.
- Investigate wider LIS/GIS research matters such as data interchange standards, sophisticated menu interface design, compatibility of software packages, time modelling and the formalisation of the user's view of reality within the suggested MULAR system.
- The overall requirement to make the system operative is the development and installation of a user-friendly interface for controlling input, model analysis, output and display. All of these currently require the operator be able to manage a variety of software packages and to be intimately familiar with the operation of the model, the data structures used and the links with the packages.

It is hoped that the benefits of the proposed methods and the MULAR system, using LIS/GIS technology, can help meet the requirement of city planners in Thailand and other developing countries in order to overcome poor land information management and the utilisation of manual procedures which have resulted in undesirable duplication that consumes time, money, and manpower.

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Appendix 3.1 The terminology of LIS/GIS.

INFORMATION SYSTEMS

The significant improvement in computer technology during the last two decades has made it much easier to apply an information system to cope with the problem of storing, manipulating and analysing large volumes of data. Lucas (1992) defines an information system as 'a set of organised procedures that, when executed, provide information for decision making, communications, and/or control of the organisation'; while Laurini and Thompson (1992) describe an information system as 'a collective of data and tools for working with those data, contains data in analog form; or digital form, about the phenomena in the real world'. Some information systems consist of subsystems, including hardware, software, and data storage for files and databases (Senn, 1989); others involve people at different levels of an organisation, computers, programs, procedures, communications' networks, and personnel to operate the system.

There is frequently debate on where the dividing lines can be drawn among information systems, for example, Geographic Information Systems (GIS), Land Information Systems (LIS), Spatial Information Systems(SIS), and so on. In many cases, the two principal terms in argument are GIS and LIS. Some taxonomies of information systems place GIS as a subset of LIS; some place LIS as a subset of GIS; others place the two on the same level, as subsets of Spatial Information Systems, using SIS as a generic name (Hazelton, 1991).

The definition of Geographic Information System (GIS)

Many attempts have been made to define what GIS is. Most definitions can be superseded by later definitions as the GIS area is still in the stages of development. Burrough (1994) simply refer to a GIS as 'a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes'. DOE (1987) defines GIS as 'an information system which can be related to specific locations on the Earth'; while Tomlinson (1987) has suggested that GIS is 'a digital system for the analysis and manipulation of a full range of geographic data, with associated systems for inputting such data for displaying the output of any analyses and manipulations'. Cowen (1988) goes on to point out that GIS is 'a decision support system involving the integration of spatially referenced data in a problem solving environment'. Aronoff (1989) also defines GIS as 'computer-based systems that are used to store and manipulate geographic information'. Star and Estates (1990) describe a GIS is 'an information system that is designed to work with data referenced by spatial or geographic coordinates'. Huxhold (1991) simply refers a GIS as 'a computerised database system for capture, storage, retrieval, analysis, and display of spatial data'. Therefore, GIS tends to be thought of as being more general in its design and application. It is aimed more at

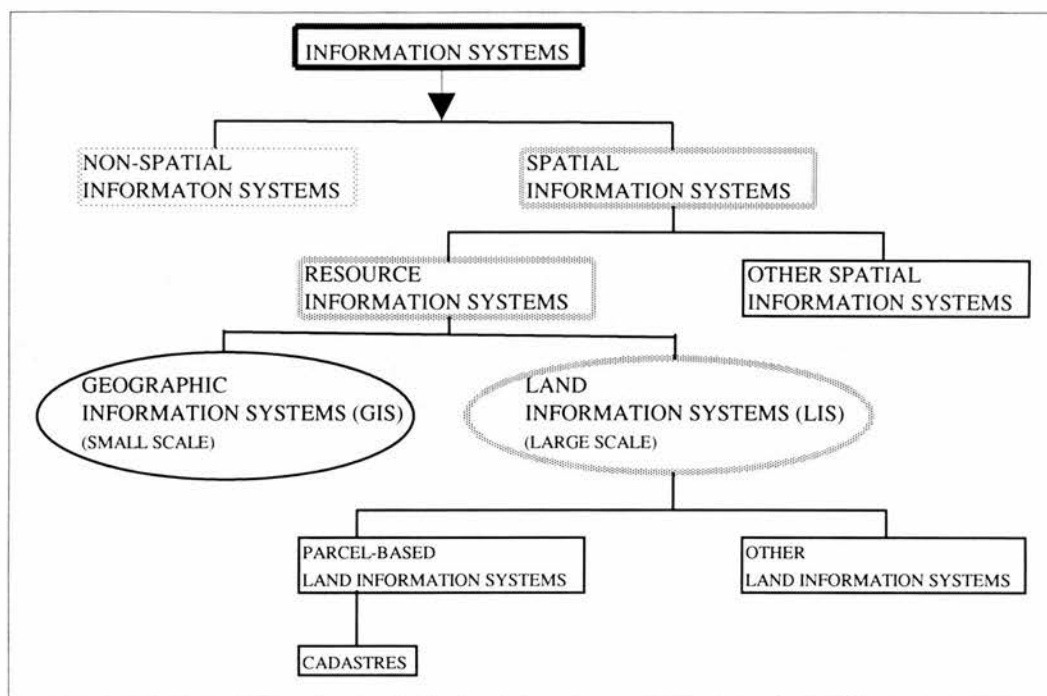
environmental land management applications and, being more small-scale, covers an area of specific interest, often not well-defined on the ground.

The definition of Land Information System (LIS)

Tinnachote (1990) points out that LIS is used for the same kind of systems which handle data at a relatively large scale while Mathieson (1992) merely refer to LIS as the result of computerisation of an organisation's land and asset related maps and plans. The best known of definition of LIS is the one adopted by FIG (International Federation of Surveyors):

'A Land Information System is a tool for legal, administrative and economic decision-making and an aid for planning and development which consists on the one hand of a database containing spatially referenced land-related data for a defined area, and on the other hand, of procedures and techniques for the systematic collection, updating, processing and distribution of the data. The base of a land information system is a uniform spatial referencing system for the data in the system, which also facilitates the linking of data within the system with other land related data' (Larsson, 1991).

As the above definition suggests, a LIS can be very complex. It not only involves procedures and equipment for handling large amounts of information, but also deals with all of the complexities of political and economic decision-making and the system of property ownership (eg land tenure) and land use management. As a result, LIS tends to be thought of as a parcel-based system. It is generally focused more on cadastral-based data applications, and at being a large-scale system. The term LIS is sometimes used synonymously with the term GIS, and SIS. A number of authors have noted significant distinctions among these different types of systems. The distinctions mainly concern the way in which the information is referenced spatially. The term LIS will therefore be used in a generic sense to refer to as a subset of Spatial Information Systems.



INFORMATION SYSTEMS TAXONOMY (based on Dale and McLaughlin, 1990)

According to the diagram shown above, the difference between a GIS and LIS is simply the scale on which the spatial data is handled (eg captured, processed, analysed, and displayed). The GIS is likely not to be thought of as a 'dynamic' system; when the database is created, there is little need to update the information. As much of the data is relatively slow changing (eg soils, geology). On the contrary, the LIS normally tends to be a 'dynamic' administrative system having integrity and accuracy.

In summary, the terms Land and Geographic Information Systems (LIS/GIS) adopted in this thesis are defined as a subset of SIS which provides a combination of human and technical resources together with a set of organising procedures which produce information for some managerial functions.

Appendix 4.1 The determination of mask angle for setting the GPS receiver.

=====
FORMULA
=====

Δh = H' * Δp

b + Δp

Tan γ = The remaining height (HT_REM)

Distance from GPS station perpendicular to the object (DIST)

Tan α = Length of object (LENGTH)

Distance from GPS station perpendicular to the object (DIST)

Where:

- H = Flying height above mean sea level,
- H' = H - h = Height above the terrain,
- h = Height of GPS station above mean sea level,
- hGPS = Height of GPS antenna above the terrain,
- b = Photo base,
- Δp = Parallax difference,
- Δh = Height difference between GPS station and the height of the object,
- γ = Vertical angle of object,
- α = Horizontal angle of object,
- Θ = Mask angle of GPS receiver.

\$ BECOME .ARC
\$ EDIT GPS.PAS

Program GPS (Input, Output);

{Declare a constant value}
const
PI = 3.14159;

{Declare the variables}
var

```

FOCAL, DELTA_P, PHOTO_B, HT_GPS, HT_AVG, DELTA_H : Real;
HT_REM, TAN_GAMMA, GAMMA, TAN_ALPHA, ALPHA : Real;
SCLAE, DIST, LENGTH : Integer;

```

```
{ Read and print input data }
```

```
begin
```

```
  WriteLn ('Input the photo scale (denominator)');
  ReadLn (SCALE);
```

```
  WriteLn ('Input the focal length (in millimetre unit)');
  ReadLn (FOCAL);
```

```
  WriteLn ('Input the parallax differences (in millimetre unit)');
  ReadLn (DELTA_P);
```

```
  WriteLn ('Input the base of photograph (in millimetre unit)');
  ReadLn (PHOTO_B);
```

```
  WriteLn ('Input the height of GPS receiver (in metre unit)');
  ReadLn (HT_GPS);
```

```
  WriteLn ('Input the distance from GPS station to base of the object (m)');
  ReadLn (DIST);
```

```
  WriteLn ('Input the length of the object (in metre unit)');
  ReadLn (LENGTH);
```

```
{ Computation of an average height of aerial camera above the terrain (HT_AVG) }
  HT_AVG := (SCALE * FOCAL) / (1000.00);
```

```
{ Computation of the height of the object (DELTA_H) }
  DELTA_H := ((HT_AVG * DELTA_P) / (PHOTO_B + DELTA_P));
```

```
{ Computation of the remaining height of the object (HT_REM) }
  HT_REM := DELTA_H - HT_GPS;
```

```
{ Computation of the tangent of GAMMA (TAN_GAMMA) }
  TAN_GAMMA := HT_REM / DIST;
```

```
{ Computation of the vertical angle of the object }
  GAMMA := ARCTAN(TAN_GAMMA) * (180.00 / PI);
```

```
{ Computation of the tangent of ALPHA (TAN_ALPHA) }
  TAN_ALPHA := LENGTH / DIST;
```

```
{ Computation of the horizontal angle of the object }
  ALPHA := ARCTAN(TAN_ALPHA) * (180.00 / PI);
```

```
[Print messages]
```



```

WriteLn;
WriteLn;
WriteLn ('An average height above the terrain (m) is', HT_AVG :14:2);
WriteLn;
WriteLn ('Height from ground to top of object (m) is', DELTA_H :14:2);
WriteLn;
WriteLn ('The remaining height difference (m) is      ', HT_REM :14:2);
WriteLn;
WriteLn ('The vertical angle of object (in degree unit) is', GAMMA :10:4);
WriteLn;
WriteLn ('The horizontal angle of the object (in degree unit) is', ALPHA :8:4);
WriteLn ('*****');
{End of the program}
end.

```

```

=====
PROCEDURE: The determination of mask angle for setting GPS receiver at
point DC13.
=====

```

```

$ PASCAL GPS.PAS
$ LINK GPS
$ RUN GPS

```

Input the photo scale (denominator)
6200 <RETURN>

Input the focal length (in millimetre unit)
304.82 <RETURN>

Input the parallax differences (in millimetre unit)
0.54 <RETURN>

Input the base of photograph (in millimetre unit)
88 <RETURN>

Input the height of GPS receiver (in metre unit)
1.265 <RETURN>

Input the distance from GPS station to base of the object (m)
26 <RETURN>

Input the length of the object (in metre unit)
14 <RETURN>

An average height above the terrain (m) is 1889.88

Height from ground to top of the object (m) is 11.53

The remaining height difference (m) is 10.26

The vertical angle of object (in degree unit) is 21.5374

The horizontal angle of object (in metre unit) is 28.0000

=====

PROCEDURE: The determination of mask angle for setting GPS receiver at point DC14.

=====

\$ PASCAL GPS.PAS
\$ LINK GPS
\$ RUN GPS

Input the photo scale (denominator)
6200 <RETURN>

Input the focal length (in millimetre unit)
304.82 <RETURN>

Input the parallax differences (in millimetre unit)
1.08 <RETURN>

Input the base of photograph (in millimetre unit)
89 <RETURN>

Input the height of GPS receiver (in metre unit)
1.354 <RETURN>

Input the distance from GPS station to base of the object (m)
42 <RETURN>

Input the length of the object (in metre unit)
120 <RETURN>

An average height above the terrain (m) is 1889.88

Height from ground to top of the object (m) is 22.66

The remaining height difference (m) is 21.30

The vertical angle of object (in degree unit) is 26.8964

The horizontal angle of object (in metre unit) is 70.000

Appendix 4.2 List of a ground control point file containing 5 full ground control points.

Point	X (m)	Y (m)	Z (m)
10011	684797.040	1521078.826	5.160
10012	684717.421	1523542.753	2.080
10013	687598.601	1523034.410	0.530
10014	687478.701	1521606.419	0.100
10015	686383.955	1522815.162	1.580

Appendix 4.3 List of a ground control point file
containing 5 full ground and 11 vertical ground control points.

Point	X (m)	Y (m)	Z (m)
10011	684797.040	1521078.826	5.160
10012	684717.421	1523542.753	2.080
10013	687598.601	1523034.410	0.530
10014	687478.701	1521606.419	0.100
10015	686383.955	1522815.162	1.580
30001	0.000	0.000	0.230
30002	0.000	0.000	0.960
30003	0.000	0.000	4.320
30004	0.000	0.000	1.110
30005	0.000	0.000	0.940
30006	0.000	0.000	1.080
30007	0.000	0.000	0.710
30008	0.000	0.000	0.900
30009	0.000	0.000	0.230
30010	0.000	0.000	1.110
30011	0.000	0.000	0.309

Appendix 4.4 List of a control point file containing 5 full ground
and 12 additional vertical control points.

Point	X (m)	Y (m)	Z (m)
10011	684797.040	1521078.826	5.160
10012	684717.421	1523542.753	2.080
10013	687598.601	1523034.410	0.530
10014	687478.701	1521606.419	0.100
10015	686383.955	1522815.162	1.580
70003	0.000	0.000	0.200
70007	0.000	0.000	1.200
70009	0.000	0.000	0.200
70011	0.000	0.000	0.400
70013	0.000	0.000	0.500
70015	0.000	0.000	0.500
70017	0.000	0.000	0.500
70021	0.000	0.000	0.700
70025	0.000	0.000	0.400
70027	0.000	0.000	0.500
70028	0.000	0.000	0.700
70029	0.000	0.000	1.100

Appendix 4.5 List of a control point file containing 5 full ground,
11 vertical ground, and 12 additional vertical control points.

Point	X (m)	Y (m)	Z (m)
10011	684797.040	1521078.826	5.160
10012	684717.421	1523542.753	2.080
10013	687598.601	1523034.410	0.530
10014	687478.701	1521606.419	0.100
10015	686383.955	1522815.162	1.580
30001	0.000	0.000	0.230
30002	0.000	0.000	0.960
30003	0.000	0.000	4.320
30004	0.000	0.000	1.110
30005	0.000	0.000	0.940
30006	0.000	0.000	1.080
30007	0.000	0.000	0.710
30008	0.000	0.000	0.900
30009	0.000	0.000	0.230
30010	0.000	0.000	1.110
30011	0.000	0.000	0.309
70003	0.000	0.000	0.200
70007	0.000	0.000	1.200
70009	0.000	0.000	0.200
70011	0.000	0.000	0.400
70013	0.000	0.000	0.500
70015	0.000	0.000	0.500
70017	0.000	0.000	0.500
70021	0.000	0.000	0.700
70025	0.000	0.000	0.400
70027	0.000	0.000	0.500
70028	0.000	0.000	0.700
70029	0.000	0.000	1.100

Appendix 4.6 List of land use classification.

Type of land use

1. Residential area
2. Commercial area
3. Industrial area
4. Warehouse
5. Agricultural area
6. Recreational area
7. Educational area
8. Religious area
9. Institutional area

(Source: Mapping division, DTCP, Thailand)

Appendix 4.7 Building type classification.

Type of building classification

1. Bungalow

- 1.1 Wooden bungalow with ground-level concrete floor
- 1.2 Wooden bungalow with wooden/concrete low platform
- 1.3 Wooden bungalow with high platform
- 1.4 Concrete bungalow with ground-level concrete floor
- 1.5 Concrete bungalow with wooden/concrete low platform
- 1.6 Concrete bungalow with high platform
- 1.7 Wooden bungalow with gypsum board and ground-level concrete floor
- 1.8 Wooden bungalow with gypsum board and wooden/concrete low platform
- 1.9 Wooden bungalow with Thai style and high platform

2. Detached house

- 2.1 Wooden detached house with ground-level concrete floor
- 2.2 Wooden detached house with wooden/concrete low platform
- 2.3 Half wooden and half concrete detached house with ground-level concrete floor
- 2.4 Half wooden and half concrete detached house with wooden/concrete low platform
- 2.5 Concrete detached house with ground-level concrete floor
- 2.6 Concrete detached house with wooden/concrete low platform
- 2.7 Wooden/concrete detached house with gypsum board and ground-level concrete floor
- 2.8 Wooden/concrete detached house with gypsum board and wooden/concrete low platform
- 2.9 Wooden detached house with gypsum board, and ground-level concrete floor
- 2.10 Wooden detached house with gypsum and wooden/concrete low platform
- 2.11 Wooden/concrete house with Thai style and ground-level concrete floor

3. Three-storey detached house

- 3.1 Wooden/concrete three-storey detached house with ground-level concrete floor
- 3.2 Concrete three-storey detached house with ground-level concrete floor

4. Terraced house

- 4.1 Wooden one-storey terraced house
- 4.2 Wooden two-storey terraced house
- 4.3 Wooden/concrete two-storey terraced house
- 4.4 Wooden/concrete two-storey terraced house with gypsum board

5. Town house

- 5.1 One-storey town house
- 5.2 Two-storey town house
- 5.3 Three-storey town house

5.4 Four-storey town house

6. Tenement house

- 6.1 One-storey tenement house
- 6.2 Two-storey tenement house
- 6.3 Three-storey tenement house
- 6.4 Four-storey tenement house
- 6.5 Five-storey tenement house
- 6.6 Six-storey tenement house

7. High-rise apartment

- 7.1 Seven-storey high-rise apartment
- 7.2 Eight-storey high-rise apartment
- 7.3 Nine-storey high-rise apartment
- 7.4 Ten-storey high-rise apartment
- 7.5 Fifteen-storey high-rise apartment
- 7.6 Twenty-storey high-rise apartment
- 7.7 Twenty-five-storey high-rise apartment
- 7.8 Thirty-storey high-rise apartment
- 7.9 Thirty-five-storey high-rise apartment
- 7.10 Forty-storey high-rise apartment
- 7.11 Forty-five-storey high-rise apartment
- 7.12 Fifty-storey high-rise apartment
- 7.13 More than fifty-storey high-rise apartment

8. Other buildings

- 8.1 Wooden warehouse
- 8.2 Concrete warehouse
- 8.3 Garage
- 8.4 Fresh-food market
- 8.5 Petrol station
- 8.6 Automobile workshop

9. Other structures

- 9.1 Swimming pool
- 9.2 Badminton court
- 9.3 Tennis court
- 9.4 Basketball court
- 9.5 Golf course
- 9.6 Football ground
- 9.7 Rugby field
- 9.8 Playground

(Source: Adapted from Assets Assessment Committee, Thailand)

Appendix 4.8 List of compensation cost of tree.

Type of tree	Price in Baht currency (depends on size of tree)		
	Big size and yields fruits	Big size, no fruit	Small size
Bamboo	200	100	40
Coconut	800	400	95
Mango	1700	800	200

Appendix 4.9 List of ground control points derived by adjusted block of SET 4.

Point	X (m)	Y (m)	Z (m)
10011	684797.040	1521078.826	5.160
10012	684717.421	1523542.753	2.080
10013	687598.601	1523034.410	0.530
10014	687478.701	1521606.419	0.100
10015	686383.955	1522815.162	1.580
30001	687331.621	1521810.067	0.230
30002	686346.090	1522325.480	0.960
30003	685761.926	1522629.491	4.320
30004	684773.985	1523146.542	1.110
30005	684700.272	1522595.272	0.940
30006	684585.671	1522570.402	1.080
30007	684685.950	1521490.975	0.710
30008	684784.676	1521525.957	0.900
30009	687604.589	1522234.820	0.230
30010	684751.537	1523820.360	1.110
30011	687527.665	1522749.854	0.309
60001	685276.311	1522747.963	1.575
60002	686317.611	1522760.537	0.878
60003	686824.923	1522743.917	0.850
60004	686973.717	1522698.848	-0.222
60005	687541.742	1522839.685	-0.804
60006	687507.817	1522635.805	0.018
60007	684626.525	1521850.381	-0.196
60008	685134.380	1521831.610	2.183
60009	685385.722	1521590.113	1.497
60010	685681.297	1521818.537	2.234
60011	685819.394	1521602.922	2.125
60012	686285.765	1521836.438	1.165
60013	686436.927	1521583.768	1.282
60014	686843.737	1521861.822	1.077
60015	686958.085	1521630.116	0.373
60016	687463.174	1521812.242	-0.066
60017	687545.736	1521654.018	-0.437
70001	685269.231	1523875.758	1.456
70002	685157.887	1523251.936	1.262
70003	685747.816	1523872.393	0.200
70004	685830.825	1523279.841	0.638
70005	686410.364	1523932.136	1.020
70006	686307.712	1523329.030	1.510
70007	686851.429	1523895.115	1.200
70008	686870.566	1523314.354	1.522

70009	687478.730	1523842.998	0.200
70010	687491.770	1523231.089	1.144
70011	684725.123	1522154.766	0.400
70012	685260.378	1522208.264	1.973
70013	685817.009	1522134.759	0.500
70014	686337.282	1522178.299	1.766
70015	687029.495	1522168.697	0.500
70016	684565.623	1521265.184	0.973
70017	684545.599	1520702.758	0.500
70018	685151.829	1521283.726	1.103
70019	685117.202	1520577.259	-0.167
70020	685685.097	1521243.226	2.179
70021	685646.734	1520617.069	0.700
70022	686375.143	1521269.971	1.750
70023	686210.561	1520681.178	1.510
70024	686912.765	1521228.175	1.173
70025	686837.588	1520749.100	0.400
70026	687533.241	1521322.587	0.212
70027	687424.494	1520745.568	0.500
70028	687616.925	1522250.694	0.700
70029	684749.745	1523902.134	1.100

Appendix 4.10 A program to convert the Z value to be a USER-ID for ARC/TIN package.

```
$ BECOME .ARC
$ EDIT RUNFORT.FOR
```

```
      IMPLICIT DOUBLE PRECISION
c      Declaration
      character*30 intf, outf
c      Write and read input file
      write(6, *) 'Input file?'
      read(5, 100) intf
100    format (a50)
      open(3, file=intf, status='old')
      write(6, *) 'Output file?'
      read(5,100)outf
      open(4, file=outf, status='new')
      npts=0
c      Read the 'old input file'
10    read(3, *, end=40),A,B,C
      npts=npts+1
      id=C*1000.0
c      Write the 'new output file'
      write(4, *)id,A,B
      goto 10
40    write(4, *) 'end'
c      Type the number of points in the output file
      write(6, *) 'End of program: npt=', npts
      stop
      end
```

```
=====
PROCEDURE: Conversion of Z value to be used as User-ID for ARC/TIN package.
=====
```

```
$ FORTRAN RUNFORT.FOR
$ LINK RUNFORT
$ RUN RUNFORT
```

Input file?
TOTDTM.GLD <RETURN>

Output file?
TOTDTM.PTS <RETURN>

End of program: npt = 2540

Appendix 5.1 The normalisation (1NF-3NF) of LIS/GIS data for urban land readjustment in Bangkok.

UNF	LEVEL	1NF	2NF	3NF	TABLE NAME
PARCEL#	1	PARCEL#	PARCEL#	PARCEL#	1) LAND
OWNER_CODE#	1	OWNER_CODE#	OWNER_CODE#	OWNER_CODE#	
TITLE_CODE#	1	TITLE_CODE#	TITLE_CODE#	TITLE_CODE#	
LAND_X	1	LAND_X	LAND_X	LAND_X	
LAND_Y	1	LAND_Y	LAND_Y	LAND_Y	
OWNER_CLASSIFICATION	1	OWNER_CLASSIFICATION	OWNER_CLASSIFICATION		
TITLE_CLASSIFICATION	1	TITLE_CLASSIFICATION	TITLE_CLASSIFICATION	OWNER_CODE# OWNER_CLASSIFICATION	
				TITLE_CODE# TITLE_CLASSIFICATION	2) OWNER_CODE
					3) TITLE_CODE
		PARCEL#	PARCEL#		4) LAND_OWNERSHIP
OWNER#	2	OWNER#	OWNER#		
OFFICIAL_AREA	2	OFFICIAL_AREA	OFFICIAL_AREA		
LAND#	2	LAND#	LAND#		
TITLE_SERIAL#	2	TITLE_SERIAL#	TITLE_SERIAL#		
VOLUME	2	VOLUME	VOLUME		
PAGE	2	PAGE	PAGE		
DOL_SHEET	2	DOL_SHEET	DOL_SHEET		
UTM_SHEET	2	UTM_SHEET	UTM_SHEET		
UTM_SERIES	2	UTM_SERIES	UTM_SERIES		
GENDER	2	GENDER			
OWNER_INITIAL	2	OWNER_INITIAL	OWNER#		
OWNER_SURNAME	2	OWNER_SURNAME	GENDER		
OWNER_ADDRESS	2	OWNER_ADDRESS	OWNER_INITIAL		
OWNER_DISTRICT	2	OWNER_DISTRICT	OWNER_SURNAME		
OWNER_POSTCODE	2	OWNER_POSTCODE	OWNER_ADDRESS		
OWNER_PROVINCE	2	OWNER_PROVINCE	OWNER_DISTRICT		
OWNER_TEL#	2	OWNER_TEL#	OWNER_POSTCODE OWNER_PROVINCE OWNER_TEL#		
		PARCEL#	PARCEL#		6) LAND_MORTGAGE
MORTGAGEE#	3	MORTGAGEE#	MORTGAGEE#		
LMORT_DATE	3	LMORT_DATE	LMORT_DATE		
LMORT_AMOUNT	3	LMORT_AMOUNT	LMORT_AMOUNT		
SEX	3	SEX			7) MORTGAGEE
MORTGAGEE_INITIAL	3	MORTGAGEE_INITIAL	MORTGAGEE#		
MORTGAGEE_SURNAME	3	MORTGAGEE_SURNAME	SEX		
MORTGAGEE_ADDRESS	3	MORTGAGEE_ADDRESS	MORTGAGEE_INITIAL		
MORTGAGEE_DISTRICT	3	MORTGAGEE_DISTRICT	MORTGAGEE_SURNAME		
MORTGAGEE_POSTCODE	3	MORTGAGEE_POSTCODE	MORTGAGEE_ADDRESS		
MORTGAGEE_PROVINCE	3	MORTGAGEE_PROVINCE	MORTGAGEE_DISTRICT		
MORTGAGEE_TEL#	3	MORTGAGEE_TEL#	MORTGAGEE_POSTCODE MORTGAGEE_PROVINCE MORTGAGEE_TEL#		
		PARCEL#			8) LAND_VALUE
LANDVALUE_YEAR	4	LANDVALUE_YEAR			
LANDVALUE	4	LANDVALUE			

UNF	LEVEL	INF	2NF	3NF	TABLE NAME
BLDG#	1	BLDG#	BLDG#	BLDG#	9) BUILDING
PARCEL#	1	PARCEL#	PARCEL#	PARCEL#	
BLDG_CODE#	1	BLDG_CODE#	BLDG_CODE#	BLDG_CODE#	
BLDG_X	1	BLDG_X	BLDG_X	BLDG_X	
BLDG_Y	1	BLDG_Y	BLDG_Y	BLDG_Y	
BLDG_CLASSIFICATION	1	BLDG_CLASSIFICATION	BLDG_CLASSIFICATION		
STOREY#	1	STOREY#		BLDG_CODE#	
FLOOR_AREA_SQWAH	1	FLOOR_AREA_SQWAH		BLDG_CLASSIFICATION	
BLDGBUILT_DATE	1	BLDGBUILT_DATE			
BLDGVALUE_YEAR	1	BLDGVALUE_YEAR	BLDG#		
BLDG_PERIOD	1	BLDG_PERIOD	STOREY#		10) BUILDING_CODE
PERCENTAGE_BLDG_DEPRECIATION	1	PERCENTAGE_BLDG_DEPRECIATION	FLOOR_AREA_SQWAH		
BLDGVALUE_SQWAH	1	BLDGVALUE_SQWAH	BLDGBUILT_DATE		
			BLDGVALUE_YEAR		
			BLDG_PERIOD		
			PERCENTAGE_BLDG_DEPRECIATION		
			BLDGVALUE_SQWAH		
OWNER#	2	BLDG# OWNER#			
STOREY#	3	BLDG# STOREY#			11) BUILDING_VALUE
MORTGAGEE#	3	MORTGAGEE#			
BLDGMORT_DATE	3	BLDGMORT_DATE			
BLDGMORT_AMOUNT	3	BLDGMORT_AMOUNT			
					12) BUILDING_OWNERSHIP
					13) BUILDING_MORTGAGE

ROAD#	1	ROAD#			14) IS_ON
PARCEL#	1	PARCEL#			
ROAD_X	1	ROAD_X			
ROAD_Y	1	ROAD_Y			
					15) ROAD
OWNER_CODE#	2	OWNER_CODE#	ROAD# OWNER_CODE#	ROAD# OWNER_CODE#	
ROAD_CODE#	2	ROAD_CODE#	ROAD_CODE#	ROAD_CODE#	
ROAD_SURFACE_TYPE#	2	ROAD_SURFACE_TYPE#	ROAD_SURFACE_TYPE#	ROAD_SURFACE_TYPE#	
ROAD_SURFACE_CLASSIFICATION	2	ROAD_SURFACE_CLASSIFICATION	ROAD_SURFACE_CLASSIFICATION		16) ROAD_SURFACE_TYPE
ROAD_CLASSIFICATION	2	ROAD_CLASSIFICATION		ROAD_SURFACE_TYPE#	
			ROAD_CODE#	ROAD_SURFACE_CLASSIFICATION	
			ROAD_CLASSIFICATION		
				ROAD_CODE#	17) ROAD_CODE
				ROAD_CLASSIFICATION	
OWNER#	3	ROAD# OWNER#			18) ROAD_OWNERSHIP
ROAD_PLACE_NAME	3	ROAD_PLACE_NAME			
RIGHT_OF_WAY	3	RIGHT_OF_WAY			
CARRIAGE_WAY	3	CARRIAGE_WAY			

VEGETATION#	1	VEGETATION#			19) PLANTED
PARCEL#	1	PARCEL#			
VEGETATION_X	1	VEGETATION_X			
VEGETATION_Y	1	VEGETATION_Y			
					20) VEGETATION
VEGETATION_CODE#	2	VEGETATION# VEGETATION_CODE#	VEGETATION#		
VEGETATION_HEIGHT	2	VEGETATION_HEIGHT	VEGETATION_CODE#		
VEGETATION_SIZE	2	VEGETATION_SIZE	VEGETATION_HEIGHT		
VEGETATION_COST	2	VEGETATION_COST	VEGETATION_SIZE		21) VEGETATION_CODE
VEGETATION_CLASSIFICATION	2	VEGETATION_CLASSIFICATION	VEGETATION_COST		
			VEGETATION_CODE#		
			VEGETATION_CLASSIFICATION		

UNF	LEVEL	INF	2NF	3NF	TABLE NAME
PARCEL#	1	<u>ELECTRICITY#</u>			22) LOCATED
ELECTRICITY#	1	<u>PARCEL#</u>			
ELECTRICITY_X	1	<u>ELECTRICITY_X</u>			
ELECTRICITY_Y	1	<u>ELECTRICITY_Y</u>			
		<u>ELECTRICITY#</u>	<u>ELECTRICITY#</u>		23) ELECTRICITY
ELECTRICIDY_CODE#	2	<u>ELECTRICIDY_CODE#</u>	<u>ELECTRICIDY_CODE#</u>		
ELECTRICITY_COST	2	<u>ELECTRICITY_COST</u>	<u>ELECTRICITY_COST</u>		
ELECTRICITY_CLASSIFICATION	2	<u>ELECTRICITY_CLASSIFICATION</u>	<u>ELECTRICIDY_CODE#</u>		24) ELECTRICITY_CODE
			<u>ELECTRICITY_CLASSIFICATION</u>		
TELEPHONE_BOOTH#	1	<u>TELEPHONE_BOOTH#</u>			25) INSTALLED
PARCEL#	1	<u>PARCEL#</u>			
TELEPHONE_BOOTH_X	1	<u>TELEPHONE_BOOTH_X</u>			
TELEPHONE_BOOTH_Y	1	<u>TELEPHONE_BOOTH_Y</u>			
		<u>TELEPHONE_BOOTH#</u>	<u>TELEPHONE_BOOTH#</u>		26) TELEPHONE
TELEPHONE_BOOTH_CODE#	2	<u>TELEPHONE_BOOTH_CODE#</u>	<u>TELEPHONE_BOOTH_CODE#</u>		
TELEPHONE_BOOTH_COST	2	<u>TELEPHONE_BOOTH_COST</u>	<u>TELEPHONE_BOOTH_COST</u>		
TELEPHONE_CODE#	2	<u>TELEPHONE_CODE#</u>	<u>TELEPHONE_CODE#</u>		
TELEPHONE#	2	<u>TELEPHONE#</u>	<u>TELEPHONE#</u>		27) TELEPHONE_BOOTH_CODE
TELEPHONE_BOOTH_CLASSIFICATION	2	<u>TELEPHONE_BOOTH_CLASSIFICATION</u>	<u>TELEPHONE_BOOTH_CODE#</u>		
			<u>TELEPHONE_BOOTH_CLASSIFICATION</u>		
TRIBUTARY#	1	<u>TRIBUTARY#</u>	<u>TRIBUTARY#</u>		28) IS_A_PART_OF
PARCEL#	1	<u>PARCEL#</u>	<u>PARCEL#</u>		
TRIBUTARY#	1	<u>TRIBUTARY#</u>	<u>TRIBUTARY#</u>		
TRIBUTARY_X	1	<u>TRIBUTARY_X</u>	<u>TRIBUTARY_X</u>		
TRIBUTARY_Y	1	<u>TRIBUTARY_Y</u>	<u>TRIBUTARY_Y</u>		29) TRIBUTARY_OWNERSHIP
OWNER#		<u>OWNER#</u>	<u>OWNER#</u>		
		<u>TRIBUTARY#</u>	<u>TRIBUTARY#</u>		30) TRIBUTARY
TRIBUTARY_CODE#	2	<u>TRIBUTARY_CODE#</u>	<u>TRIBUTARY_CODE#</u>		
TRIBUTARY_PLACE_NAME	2	<u>TRIBUTARY_PLACE_NAME</u>	<u>TRIBUTARY_PLACE_NAME</u>		
TRIBUTARY_WIDTH	2	<u>TRIBUTARY_WIDTH</u>	<u>TRIBUTARY_WIDTH</u>		
OWNER_CODE#	2	<u>OWNER_CODE#</u>	<u>OWNER_CODE#</u>		31) TRIBUTARY_CODE
TRIBUTARY_CLASSIFICATION	2	<u>TRIBUTARY_CLASSIFICATION</u>	<u>TRIBUTARY_CODE#</u>		
			<u>TRIBUTARY_CLASSIFICATION</u>		
WATERWORKS#	1	<u>WATERWORKS#</u>			32) LAIN
PARCEL#	1	<u>PARCEL#</u>			
WATERWORKS_X	1	<u>WATERWORKS_X</u>			
WATERWORKS_Y	1	<u>WATERWORKS_Y</u>			
		<u>WATERWORKS#</u>	<u>WATERWORKS#</u>		33) WATER_WORKS
WATERWORKS_CODE#	2	<u>WATERWORKS_CODE#</u>	<u>WATERWORKS_CODE#</u>		
WATERWORKS_COST	2	<u>WATERWORKS_COST</u>	<u>WATERWORKS_COST</u>		
WATERWORKS_CLASSIFICATION	2	<u>WATERWORKS_CLASSIFICATION</u>	<u>WATERWORKS_CODE#</u>		34) WATERWORKS_CODE
			<u>WATERWORKS_CLASSIFICATION</u>		
LANDUSE_CODE#	1	<u>LANDUSE_CODE#</u>			35) LAND_USE
PARCEL#	1	<u>PARCEL#</u>			
LANDUSE_YEAR	1	<u>LANDUSE_YEAR</u>			
		<u>LANDUSE_CODE#</u>			36) LANDUSE_CODE
LANDUSE_CLASSIFICATION	2	<u>LANDUSE_CLASSIFICATION</u>			

UNF	LEVEL	INF	2NF	3NF	TABLE NAME
GEOLOGY#	1	GEOLOGY#			37) GEOLOGY
PARCEL#	1	PARCEL#			
		GEOLOGY#			38) GEOLOGY_CODE
ROCK_TYPE	2	ROCK_TYPE			
FORMATION	2	FORMATION			
GROUP	2	GROUP			
AGE	2	AGE			

SOIL#	1	SOIL#			39) SOIL
PARCEL#	1	PARCEL#			
		SOIL#			40) SOIL_CODE
SOIL_SERIES	2	SOIL_SERIES			
SOIL_CLASSIFICATION	2	SOIL_CLASSIFICATION			

Appendix 5.2 The primary and foreign keys in the database system.

LAND

- 1) **LAND** (PARCEL#, *OWNER_CODE#, *TITLE_CODE#, LAND_X, LAND_Y)
- 2) **OWNER_CODE** (OWNER_CODE#, OWNER_CLASSIFICATION)
- 3) **TITLE_CODE** (TITLE_CODE#, TITLE_CLASSIFICATION)
- 4) **LAND_OWNERSHIP** (PARCEL#, OWNER#, OFFICIAL_AREA, LAND#, TITLE_SERIAL#, VOLUME, PAGE, DOL_SHEET, UTM_SHEET, UTM_SERIES)
- 5) **OWNER** (OWNER#, GENDER, OWNER_INITIAL, OWNER_SURNAME, OWNER_ADDRESS, OWNER_DISTRICT, OWNER_POSTCODE, OWNER_PROVINCE, OWNER_TEL#)
- 6) **LAND_MORTGAGE** (PARCEL#, *MORTGAGEE#, LMORT_DATE, LMORT_AMOUNT)
- 7) **MORTGAGEE** (MORTGAGEE#, SEX, MORTGAGEE_INITIAL, MORTGAGEE_SURNAME, MORTGAGEE_ADDRESS, MORTGAGEE_DISTRICT, MORTGAGEE_POSTCODE, MORTGAGEE_PROVINCE, MORTGAGEE_TEL#)
- 8) **LAND_VALUE** (PARCEL#, LANDVALUE_YEAR, LANDVALUE)

BUILDING

- 9) **BUILDING** (BLDG#, PARCEL#, *BLDG_CODE#, BLDG_X, BLDG_Y)
- 10) **BUILDING_CODE** (BLDG_CODE#, BLDG_CLASSIFICATION)
- 11) **BUILDING_VALUE** (BLDG#, STOREY#, FLOOR_AREA_SQWAH, BLDGBUILT_DATE, BLDGVALUE_YEAR, BLDG_PERIOD, PERCENTAGE_BLDG_DEPRECIATION, BLDGVALUE_SQWAH)
- 12) **BUILDING_OWNERSHIP** (BLDG#, *OWNER#)
- 13) **BUILDING_MORTGAGE** (BLDG#, STOREY#, *MORTGAGEE#, BLDGMORT_DATE, BLDGMORT_AMOUNT)

ROAD

- 14) **IS_ON** (ROAD#, PARCEL#, ROAD_X, ROAD_Y)

15) **ROAD** (ROAD#, *OWNER_CODE#, *ROAD_CODE#,
*ROAD_SURFACE_TYPE#)

16) **ROAD_SURFACE_TYPE** (ROAD_SURFACE_TYPE#,
ROAD_SURFACE_CLASSIFICATION)

17) **ROAD_CODE** (ROAD_CODE#, ROAD_CLASSIFICATION)

18) **ROAD_OWNERSHIP** (ROAD#, *OWNER#, ROAD_PLACE_NAME,
RIGHT_OF_WAY, CARRIAGE_WAY)

VEGETATION

19) **PLANTED** (VEGETATION#, PARCEL#, VEGETATION_X,
VEGETATION_Y)

20) **VEGETATION** (VEGETATION#, *VEGETATION_CODE#,
VEGETATION_HEIGHT, VEGETATION_SIZE, VEGETATION_COST)

21) **VEGETATION_CODE** (VEGETATION_CODE#,
VEGETATION_CLASSIFICATION)

ELECTRICITY

22) **LOCATED** (ELECTRICITY#, PARCEL#, ELECTRICITY_X,
ELECTRICITY_Y)

23) **ELECTRICITY** (ELECTRICITY#, *ELECTRICITY_CODE#,
ELECTRICITY_COST)

24) **ELECTRICITY_CODE** (ELECTRICITY_CODE#,
ELECTRICITY_CLASSIFICATION)

TELEPHONE

25) **INSTALLED** (TELEPHONE_BOOTH#, PARCEL#,
TELEPHONE_BOOTH_X, TELEPHONE_BOOTH_Y)

26) **TELEPHONE** (TELEPHONE_BOOTH#, *TELEPHONE_BOOTH_CODE#,
TELEPHONE_BOOTH_COST, TELEPHONE_CODE#, TELEPHONE#)

27) **TELEPHONE_BOOTH_CODE** (TELEPHONE_BOOTH_CODE#,
TELEPHONE_BOOTH_CLASSIFICATION)

TRIBUTARY

28) **IS_A_PART_OF** (TRIBUTARY#, PARCEL#, TRIBUTARY_X,
TRIBUTARY_Y)

29) **TRIBUTARY_OWNERSHIP** (TRIBUTARY#, *OWNER#)

30) **TRIBUTARY** (TRIBUTARY#, *TRIBUTARY_CODE#,
TRIBUTARY_PLACE_NAME, TRIBUTARY_WIDTH, *OWNER_CODE#)

31) **TRIBUTARY_CODE** (TRIBUTARY_CODE#,
TRIBUTARY_CLASSIFICATION)

WATER WORKS

32) **LAIN** (WATERWORKS#, PARCEL#, WATERWORKS_X,
WATERWORKS_Y)

33) **WATER_WORKS** (WATERWORKS#, *WATERWORKS_CODE#,
WATERWORKS_COST)

34) **WATERWORKS_CODE** (WATERWORKS_CODE#,
WATERWORKS_CLASSIFICATION)

LAND USE

35) **LAND_USE** (*LANDUSE_CODE#, PARCEL#, LANDUSE_YEAR)

36) **LANDUSE_CODE** (LANDUSE_CODE#, LANDUSE_CLASSIFICATION)

GEOLOGY

37) **GEOLOGY** (GEOLOGY#, PARCEL#)

38) **GEOLOGY_CODE** (GEOLOGY#, ROCK_TYPE, FORMATION, GROUP,
AGE)

SOIL

39) **SOIL** (SOIL#, PARCEL#)

40) **SOIL_CODE** (SOIL#, SOIL_SERIES, SOIL_CLASSIFICATION)

Appendix 5.3 Embedded SQL using C language.

```

$BEC .ARC.LAD
$EDIT CHAP53.PC

#include <stdio.h>
#include <stdlib.h>

/* Declare section */
EXEC SQL BEGIN DECLARE SECTION;
    VARCHAR    uid[5];
    VARCHAR    pwd[10];
    int         veget;          /* Retrieved the vegetation-id number */
    int         veget_cost;     /* Retrived the current vegetation cost */
EXEC SQL END DECLARE SECTIION;
EXEC SQL INCLUDE ORA_PROC: SQLCA;

main ()
{
    strcpy(uid.arr, "DC");
    uid.len = strlen(uid.arr);
    strcpy(pwd.arr, "APPLE");
    pwd.len = strlen(pwd.arr);

/* Set up error processing */
EXEC SQL WHENEVER SQLERROR GOTO sqlerror;

/* Connect to ORACLE */
EXEC SQL CONNECT :uid IDENTIFIED BY :pwd;

    printf ("\n\nConnect to ORACLE user: %s\n\n", uid.arr);
    printf ("VEGETATION#      VEGETATION_COST  \n");
    printf ("_____      _____  \n");

/* Declare the cursor for the query */
EXEC SQL DECLARE C1 CURSOR FOR
    SELECT VEGETATION#, VEGETATION_COST
        FROM VEGETATION, VEGETATION_CODE
        WHERE VEGETATION_HEIGHT > 7
        AND VEGETATION_SIZE = 'MEDIUM'
        AND VEGETATION_CLASSIFICATION = 'BAMBOO'
        ORDER BY VEGETATION#;

/* Open the cursor to start the query */
EXEC SQL OPEN C1;

```

```
EXEC SQL WHENEVER NOT FOUND GOTO stop;
```

```
/* Loop through each row of query results */
for ( ; ; )
{
    /* Fetch the next row of query results */
    EXEC SQL FETCH C1
        INTO :veget, :veget_cost;

    /* Display the retrieve data */
    printf ("%6d %22d\n", veget, veget_cost);
}
```

```
stop:
    EXEC SQL CLOSE C1;
    EXEC SQL COMMIT WORK RELEASE;
    exit(0);
```

```
sqlerror:
    Printf ("\n\nSQL error: %1d\n\n", sqlca.sqlerrm.sqlerrmc);
    EXEC SQL WHENEVER SQLERROR CONTINUE;
    EXEC SQL ROLLBACK WORK RELEASE;
    exit(1);
```

```
}
[CTRL] [Z]
*EX
$PCL CHAP53.PC
$RUN CHAP53
(The result of running the program)
```

Connect to ORACLE user: DC

<u>VEGETATION#</u>	<u>VEGETATION_COST</u>
3	100
4	100
6	100
11	100

Appendix 5.4 Embedded SQL using FORTRAN language.

\$BEC.ARC.LAD

\$EDIT CHAP54.PFO

```

C      Declare section
      IMPLICIT NONE
      INTEGER I
      EXEC SQL BEGIN DECLARE SECTION
      CHARACTER*5    UID
      CHARACTER*10   PASWD
      INTEGER        VEGET
      INTEGER        VEGET_COST
      EXEC SQL END DECLARE SECTION
      EXEC SQL INCLUDE SYS$ORACLE: SQLCA.FOR
C
C      Declare the action to be taken in case of an ORACLE error
      EXEC SQL WHENEVER SQLERROR GOTO 999
C
C      Connect to ORACLE6
      UID = 'DC'
      PASWD = 'APPLE'
      EXEC SQL CONNECT :UID IDENTIFIED BY :PASWD
C
      WRITE (*, 100) UID
100    FORMAT ('/Connect to ORACLE user: ', A10)
C
C      Declare the cursor for the query
      EXEC SQL DECLARE C1 CURSOR FOR
+SELECT VEGETATION#, VEGETATION_COST
+      FROM VEGETATION, VEGETATION_CODE
+      WHERE VEGETATION_HEIGHT > 7
+      AND VEGETATION_SIZE = 'MEDIUM'
+      AND VEGETATION_CLASSIFICATION = 'BAMBOO'
+      ORDER BY VEGETATION#
C
C      Open the cursor to start the query
      EXEC SQL OPEN C1
      WRITE (*, 110)
110    FORMAT ('/VEGETATION#      VEGETATION_COST')
      WRITE (*, 115)
115    FORMAT ('/-----')
C
C      Loop through each row of query results
      EXEC SQL WHENEVER NOT FOUND GOTO 700

```

```

200  CONTINUE
      EXEC SQL FETCH C1 INTO :VEGET, :VEGET_COST
      WRITE (*, 120) VEGET, VEGET_COST
120  FORMAT (3X, I6, 5X, I10)
      GOTO 200
700  CONTINUE
      WRITE (*, 130) SQLERD(3)
130  FORMAT (/, 2X, I6, ' ROW(S) SELECTED')
      EXEC SQL CLOSE C1
      EXEC SQL COMMIT WORK RELEASE
      STOP

C
C    Error handling routine
999  CONTINUE
      WRITE (*, 140) SQLCDE
140  FORMAT ('ORACLE6 ERROR : CODE IS ', I5)
      WRITE (*, 150)(SQLEMC (I), I = 1, 70)
150  FORMAT ('MESSAGE IS : ', 70 A1)
      EXEC SQL WHENEVER SQLERROR CONTINUE
      EXEC SQL ROLLBACK WORK RELEASE
      STOP
      END

```

[CTRL] [Z]

*EX

```

$PROFOR INAME=CHAP54.PFO ONAME=CHAP54.FOR
INCLUDE=ORA_PROFOR:
$FORTRAN CHAP54.FOR
$LNPROFOR CHAP54 CHAP54
$RUN CHAP54

```

(The result of running the program)

```

LINK TO ORACLE6 AS USER : DC

```

<u>VEGETATION#</u>	<u>VEGETATION_COST</u>
3	100
4	100
6	100
11	100

Appendix 6.1 The main program of the MULAR system in the Klong Toei project.

```
/* AML NAME: START1.AML
```

```
/* ERROR HANDLING
```

```
&SEVERITY &WARNING &IGNORE
```

```
&SEVERITY &ERROR &ROUTINE PROBLEM
```

```
/* SET DISPLAY AND DEVICE INPUT
```

```
&TYPE
```

```
&TYPE
```

```
&TYPE
```

```
&S .DEVICE = [RESPONSE 'Please enter a graphic device's code']
```

```
&TERMINAL %.DEVICE% &MOUSE
```

```
/* DISPLAY A SCROLLABLE HELP TEXT FILE AT THE TERMINAL
```

```
&POPUP [DC.ARC.KLONG]INTRO1.HLP 20 75 0 0
```

```
&MESSAGES &OFF
```

```
/* CALL CHOICE MENU
```

```
&MENU CHOICE1.MENU
```

```
/* LEAVE THE SYSTEM
```

```
QUIT
```

Appendix 6.2 The main choice menu bar in the Klong Toei project.

1 CHOICE1 MENU

EDITING

```
'Edit Road Network' &R EDITING1 COPLR1
'Edit Replotting' &R EDITING20
'Edit Electric Poles, 12 m High' &R EDITING3
'Edit Electric Poles, 8.5 m High' &R EDITING4
'Edit Electric Poles, 40w Bulbs' &R EDITING5
'Edit Electric Lines, 24 Kv' &R EDITING6
'Edit Electric Lines, 220 v' &R EDITING7
'Edit Drainage System' &R EDITING8
'Edit Water Pipes' &R EDITING9
'Edit Fire Hydrants' &R EDITING10
'Edit Telephone Cables' &R EDITING11
'Edit Telephone Booths' &R EDITING12
'Edit Proposed Buildings' &R EDITING13
''
'Help on Editing' &POPUP [DC.ARC.KLONG]EDITING.HLP 20 75 0 0
/*
```

ANALYSIS

```
'Road Network' &R ANALY1 COPLR1
'Replotting' &R ANALY2 REPLOT
'Electric Poles, 12 m High' &R ANALY3 E12HIGH
'Electric Poles, 8.5 m High' &R ANALY4 E8HIGH
'Electric Poles, 40w Bulbs' &R ANALY5 E40W
'Electric Lines, 24 Kv' &R ANALY6 E24KV
'Electric Lines, 220 v' &R ANALY7 E220V
'Drainage System' &R ANALY8 DRAIN
'Water Pipes' &R ANALY9 WATER
'Fire Hydrants' &R ANALY10 HYDRANT
'Telephone Cables' &R ANALY11 PHOCABLE
'Telephone Booths' &R ANALY12 PHOBOOTH
'Master Concept Plan1' &R ANALY13 LUSE94
'Proposed Buildings' &R ANALY14 COPBLDG
'Land Use 1992' &R ANALY15 LUSE92
'Building Types 1992' &R ANALY16 BLDG92
'Master Concept Plan2' &R ANALY17 STU2111
''
'Help on Analysis' &POPUP [DC.ARC.KLONG]ANALYSIS.HLP 20 75 0 0
/*
```

QUERY

```
'Query Land Value 1994' &R QLV94 LV94
'Query Land Value 1992' &R QLV92 LV92
```

'Query Land Value 1988' &R QLV88 LV88
 'Query Land Value 1985' &R QLV85 LV85
 'Query Land Value 1982' &R QLV82 LV82
 'Query Land Value 1979' &R QLV79 LV79
 'Query Land Value 1976' &R QLV76 LV76
 ''

'Help on Query' &POPUP [DC.ARC.KLONG]QUERY.HLP 20 75 0 0
 /*

DISPLAY

'Display Elec Pole, 12 m' &R D12HIGH E12HIGH
 'Display Elec Pole, 8.5 m' &R D8HIGH E8HIGH
 'Display Elec Pole, 40w' &R D40W E40W
 'Display Elec 24 Kv' &R D24KV E24KV
 'Display Elec 220 v' &R D220V E220V
 'Display Drainage System' &R DDRAIN DRAIN
 'Display Water Supply' &R DWATER WATER
 'Display Fire Hydrant' &R DHYDRANT HYDRANT
 'Display Telephone Cables' &R DCABLE PHOCABLE
 'Display Telephone Booths' &R DBOOTH PHOBOOTH
 'Display Land Value 1994' &R KLV94 LV94
 'Display Land Value 1992' &R KLV92 LV92
 'Display Land Value 1988' &R KLV88 LV88
 'Display Land Value 1985' &R KLV85 LV85
 'Display Land Value 1982' &R KLV82 LV82
 'Display Land Value 1979' &R KLV79 LV79
 'Display Land Value 1976' &R KLV76 LV76
 'Display Master Concept Plan1' &R DMASTER1 LUSE94
 'Display Master Concept Plan2' &R DMASTER2 STU2111
 'Display Land Before Replotting' &R DBEFORELP BEFORELP
 'Display Land After Replotting' &R DAFTERLP AFTERLP
 'Display Base Map' &R DBASEMAP CADAS
 'Display Land Use 1992' &R DLUSE92 LUSE92
 'Display Building 1992' &R DBLDG92 BLDG92
 'Display After LR Study2' &R DAFTER2 USTUDY2

/*

PRINTOUT

'Print output of maps' &R PRINTMAP
 ''

'Help on print out' &POPUP [DC.ARC.KLONG]PRINTOUT.HLP 20 75 0 0

/*

HELP &POPUP [DC.ARC.KLONG]CHOICE.HLP 20 75 0 0

/*

QUIT &RETURN

Appendix 6.3 The menu options in the Klong Toei project.

1

TOLERANCES

'Set Edit Distance' EDITDISTANCE *
 'Set Node Snapping' NODESNAP CLOSEST *
 'Set Snap Tolerance' SNAPPING CLOSEST *
 'Set Weed Tolerance' WEEDTOL *

ENVIRONMENT

'Set Edit Feature' EF [GETCHOICE ARC NODE LABEL TIC]
 'Draw Arcs On' DRAWENV ARC
 'Draw Arcs Off' DRAWENV ARC OFF
 'Draw Labels On' DRAWENV LABEL
 'Draw Labels Off' DRAWENV LABEL OFF
 'Draw Tics On' DRAWENV TIC
 'Draw Tics Off' DRAWENV TIC OFF
 'Draw Node Errors On' DRAWENV NODE ERRORS; NODECOLOR DANGLE 2; ~
 NODECOLOR PSEUDO 3
 'Draw Node Errors Off' DRAWENV NODE OFF
 'Textitem On' &S FEATURE [GETCHOICE ARC LABEL -PROMPT 'Select Feature']; ~
 TEXTITEM %FEATURE% [GETITEM %COVNAME% -%FEATURE% -ALL -ALL 'Select item']
 'Set Map Extent' MAPEX *
 'Reset to Default Map Extent' MAPEX DEFAULT

DRAW DRAW

SELECT

'Select One' SELECT
 'Select Many' SELECT MANY
 'Select Box' SELECT BOX
 'Add to Select' ASEL
 'Unselect One' UNSEL
 'Select All' SELECT ALL

ARC

'Add Arc' &IF [SHOW EDITFEATURE] NE ARC &THEN; EF ARC; ADD
 'Delete Selection' &IF [SHOW EDITFEATURE] EQ ARC &THEN; &DO; ~
 &IF [SHOW NUMBER SELECT] GT 0 &THEN; DELETE; &ELSE; &TYPE ~
 WARNING - No Arcs Selected; &END; &ELSE; &TYPE WARNING - Edit ~
 Feature is not ARC
 'Split Arc' &IF [SHOW EDITFEATURE] = ARC &THEN; &DO; SELECT; SPLIT; &END; ~
 &ELSE &TYPE ERROR - EDITFEATURE IS NOT ARC
 'Unsplit Selected Arcs' &IF [SHOW EDITFEATURE] = ARC AND [SHOW NUMBER SELECT] ~
 GT 1 &THEN; UNSPLIT; &ELSE; &TYPE WARNING - Either Editfeature is not ARC or ~
 less than 2 arcs selected.
 'Move Selection' MOVE
 'Oops' OOPS

LABEL

'Add Label' &IF [SHOW EDITFEATURE] NE LABEL &THEN; EF LABEL; ADD
 'Delete Selection' &IF [SHOW EDITFEATURE] EQ LABEL &THEN; &DO; ~
 &IF [SHOW NUMBER SELECT] GT 0 &THEN; DELETE; &ELSE; &TYPE ~
 WARNING - No Labels Selected; &END; &ELSE; &TYPE WARNING - Edit ~
 Feature is not LABEL.
 'Move Selection' MOVE
 'Oops' OOPS

NODE

'Move' &IF [SHOW EDITFEATURE] NE NODE &THEN; EF NODE; MOVE

'Oops' OOPS

QUIT

'Save' SAVE; QUIT; &RETURN

'Save & Quit' SAVE ALL YES; QUIT; &RETURN

'Quit Only' QUIT; NO; &RETURN

HELP

'Help on TOLERANCES' &POPUP [DC.ARC.KLONG]TOLERANCE.HLP 20 75 0 0

'Help on HELP' HELP COMMAND

Appendix 6.4 The 'modular programming' in the editing capability.

```

/* AML NAME: EDITING6.AML

/* ERROR HANDLING
&SEVERITY &WARNING &IGNORE
&SEVERITY &ERROR &ROUTINE PROBLEM
&MESSAGES &ON

/* CREATE AN EMPTY COVERAGE FROM COPLR111 (Polygon coverage) IN ARC
ENVIRONMENT
&SV COV1 = E24KV
&SV MASTER = COPLR11
CREATE %COV1% %MASTER%

/* SET UP ARCEDIT ENVIRONMENT
ARCEDIT

/* SET UP DEVICE DISPLAY
&SV DEVICE = [GETCHOICE 4207 9999 'Please select a graphic device"s code']
DISPLAY %DEVICE%

/* SPECIFY A COVERAGE THAT WILL BE USED AS A BACKGROUND DISPLAY
BACKCOV %MASTER% 2

/* SPECIFY WHICH FEATURE CLASSES WILL BE DISPLAYED IN BACKGROUND
COVERAGES
BACKENV ARC

/* DRAW THE EDITING COVERAGE
MAPEXTENT %COV1%
EDITCOVERAGE %COV1%

DRAWENV ARC

DRAW

/* SET UP EDITING MENU
&MENU EDIT1

&MESSAGES &OFF

/* ERROR HANDLING ROUTINE
&ROUTINE PROBLEM
&RETURN

```

Appendix 6.5 A program to link and retrieve data from the ORACLE database.

```

/* AML NAME: QLV92.AML

&ARGS COVNAME

/* ERROR HANDLING
&SEVERITY &WARNING &IGNORE
&SEVERITY &ERROR &ROUTINE PROBLEM
&MESSAGES &ON

&TYPE
&TYPE
&TYPE
&TYPE "Please wait...Connecting ARC/INFO with ORACLE!!!"

CONNECT ORACLE DC/APPLE

/* RELATE PROCEDURE
RELATE ADD

R92
KLAND_VALUE
ORACLE
LV92-ID
PARCEL#
ORDERED
RW
~

&IF [EXISTS %COVNAME% -POLY] &THEN
  &DO
    INDEXITEM LV92.PAT LV92-ID
    RELATE SAVE SR92.REL
  &END

&TYPE
&TYPE
&TYPE
&TYPE "Please wait...Setting up ARCPLOT environment!!!"
&TYPE
&TYPE
&TYPE
&TYPE
&TYPE
&TYPE

ARCPLOT

/* SET UP TERMINAL ENVIRONMENT
&TYPE
&TYPE
&TYPE
&SV DEVICE = [GETCHOICE 4207 9999 'Please select a graphic device's code']
DISPLAY %DEVICE%
```

```

&SV RELNAME = R92
&SV RELRES = SR92.REL
RELATE RESTORE %RELRES%
/*
MAPEX %COVNAME%
POLYS %COVNAME%
RESELECT %COVNAME% POLY ^%RELNAME% WHERE LANDVALUE_YEAR = 1992 AND
~ LANDVALUE = 30000
POLYGONSHADES %COVNAME% 11
CLEARSELECT

RESELECT %COVNAME% POLY ^%RELNAME% WHERE LANDVALUE_YEAR = 1992 AND
~ LANDVALUE = 35000
POLYGONSHADES %COVNAME% 7
CLEARSELECT

RESELECT %COVNAME% POLY ^%RELNAME% WHERE LANDVALUE_YEAR = 1992 AND
~ LANDVALUE = 50000
POLYGONSHADES %COVNAME% 10
CLEARSELECT

RESELECT %COVNAME% POLY ^%RELNAME% WHERE LANDVALUE_YEAR = 1992 AND
~ LANDVALUE = 80000
POLYGONSHADES %COVNAME% 6
CLEARSELECT

LINECOLOR 1
ARCS %COVNAME%

&TYPE
&TYPE
&TYPE
&TYPE "Hit <RETURN>, when you would like to exit to MULAR module."
&TYPE
&TYPE

&PAUSE

QUIT

&MESSAGES &OFF

/* EXIT TO THE MULAR MODULE
&RETURN
/*
/* ERROR HANDLING ROUTINE
&ROUTINE PROBLEM
&SEVERITY &ERROR &IGNORE
&TYPE "Problem with your program - Please try again"
&RETURN

```

Appendix 6.6 A program to create a three-dimensional viewing in the MULAR system.

```

/* AML NAME: DMIN3D.AML

&ARGS COVNAME

/* ERROR HANDLING
&SEVERITY &WARNING &IGNORE
&SEVERITY &ERROR &ROUTINE PROBLEM
&MESSAGES &ON

&TYPE
&TYPE
&TYPE
&TYPE "Please wait...Setting up ARCPLOT environment!!!"
&TYPE
&TYPE
&TYPE
&TYPE
&TYPE

ARCPLOT

&SV DEVICE = [GETCHOICE 1040 4207 9999 'Please select the device"code']
DISPLAY %DEVICE%

/* PLOT FILE
FLAT1.GRA

MAPEX %COVNAME%
PAGEUNITS CM
PAGESIZE 21 29.7
MAPUNITS METERS
MAPSCALE 20000
MAPLIMITS 4.5 7 17.5 22
LINECOLOR 1

SURFACE LATTICE %COVNAME% 100
SURFACELIMITS 4.5 7 17.5 22
SURFACEEXTENT SURFACE, 686300, 1522000, 687000, 1523000
SURFACETARGET 686700, 1522500
SURFACEOBSERVER RELATIVE 225 35 1000
SURFACEVIEWFIELD AUTOMATIC
SURFACEDRAPE MESH FISHNET 10

/* DRAPE A POLYGON GRAPHIC FILE SO-CALLED 'TINCADAS.GRA'
SURFACEDRAPE GRAPHICSFILE TINCADAS.GRA

/* DRAPE A POLYGON GRAPHIC FILE SO-CALLED 'TINBLDG.GRA'
SURFACEDRAPE GRAPHICSFILE TINBLDG.GRA

/* DRAPE A POINT COVERAGE SO-CALLED 'INTBAM'
MARKERSYMBOL 50

```

MARKERSIZE 0.2
SURFACEDRAPE POINTS INTBAM

/* DRAPE A POINT COVERAGE SO-CALLED 'INTCO'
MARKERSYMBOL 51
MARKERSIZE 0.2
SURFACEDRAPE POINTS INTCO

/* DRAPE A POINT COVERAGE SO-CALLED 'INTMAN'
MARKERSYMBOL 52
MARKERSIZE 0.2
SURFACEDRAPE POINTS INTMAN

LINECOLOR 1
BOX 4 6 18 23.5
BOX 4.5 6.5 17.5 23
/*
MARKERSYMBOL 57
MARKERCOLOR 1
MARKERSIZE 1
MARKERANGLE 45
MARKER 5.8 21.3

/*
MOVE 5.2 21.8
TEXTANGLE 45
TEXTFONT 9
TEXTSIZE 0.35
TEXTCOLOR 2
TEXT 'N'

/*
MOVE 12.1 22
TEXTANGLE 0
TEXTSIZE 0.25
TEXTCOLOR 1
TEXTSPACING 1
TEXT 'Altitude 35 degrees'

/*
MOVE 12.1 21
TEXT 'Azimuth 225 degrees'

/*
MOVE 12.1 20
TEXT 'Height exaggeration 100 times'

/*
MOVE 11 6.8
TEXT 'Map compiled by DUSDI CHANLIKIT 1995'

/*
MOVE 5 5.5
TEXTSIZE 0.3
TEXT 'Figure 6.2 A three dimensional viewing in the Lad Krabang Project.'

/*
MOVE 5 12.5
TEXT 'LEGEND'

/*
KEYPOSITION 5 9
KEYBOX 0.5 0.5

KEYSEPARATION 0.5 0.5
TEXTSIZE 0.25
KEYSHADE [DC.ARC.LAD]DBLDG.LEG

KEYPOSITION 5 12
KEYBOX 0.5 0.5
KEYMARKER [DC.ARC.LAD]DBAM.LEG
/*

KEYPOSITION 5 11
KEYBOX 0.5 0.5
KEYMARKER [DC.ARC.LAD]DCO.LEG
/*

KEYPOSITION 5 10
KEYBOX 0.5 0.5
KEYMARKER [DC.ARC.LAD]DMAN.LEG

/*&PAUSE

QUIT

&MESSAGES &OFF

/* EXIT TO THE MULAR MODULE
&RETURN

/*
/* ERROR HANDLING ROUTINE
&ROUTINE PROBLEM
&SEVERITY &ERROR &IGNORE
&TYPE "Problem with your program - Please try again"
&RETURN

Appendix 6.7 Bangkok Metropolitan General Plan for a medium density residential area.

In compliance with the Bangkok Metropolitan General Plan, the layout of master concept plan is primarily for medium density residential area. In principle, the following uses are prohibited:

- All kinds of factories except service industries, household industries which caused no disturbances or non-polluting industries.
- Warehouses.
- Petrol warehouses for wholesale distribution.
- Gas storage, excepting gas retail shops and service stations.
- Warehouse of explosives or poisonous products.
- Livestock farms, wild animals, or others which are likely to cause disturbances.
- Silo for agricultural product.
- Cemetery or crematorium except construction of a building on the same plot.
- Disposal of rubbish.
- Pleasure park.
- Transaction of scrap waste materials.

Source: Ministerial Regulation, No. 116 (1992), MOI.

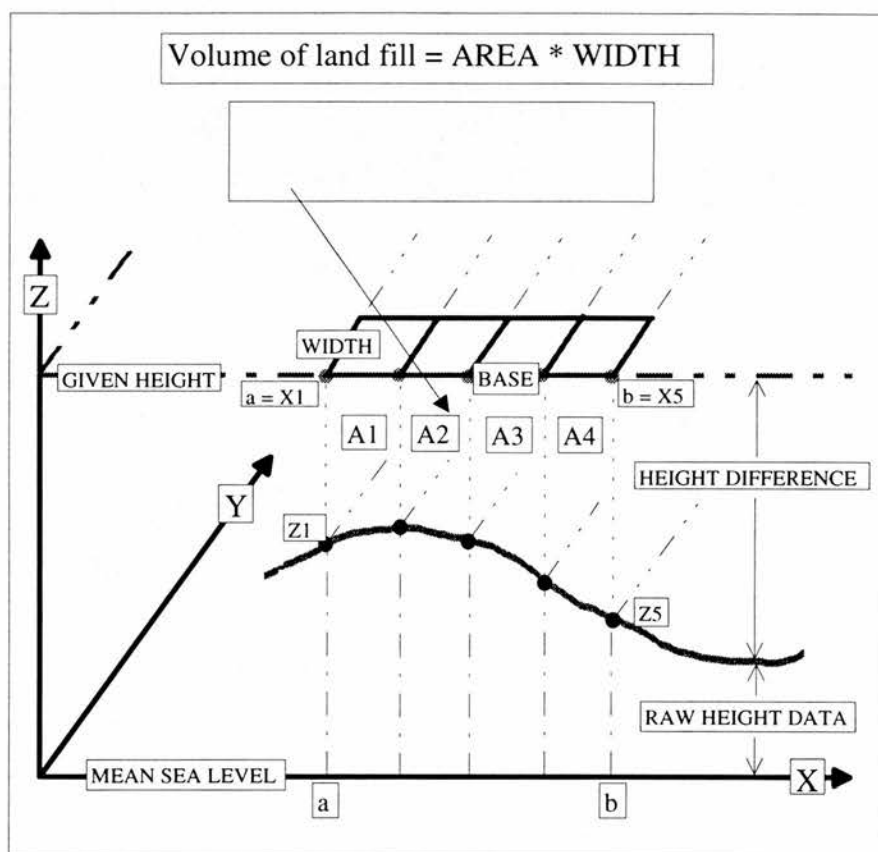
Appendix 6.8 Bangkok Metropolitan General Plan for a low density residential area.

In compliance with the Bangkok Metropolitan General Plan, the layout of master concept plan is also focused on low density residential areas. In general, the following details are prohibited:

- Large buildings commercial development (larger than 10,000 sq. metres of gross floor area).
- All kinds of factories except service industries, household industries, extension of existing factories on the same plot belonging to the same owners and which are non-polluting industries.
- Warehouses.
- Petrol warehouses for wholesale distribution.
- Gas storage, excepting gas retail shops and service stations.
- Warehouse of explosives or poisonous products.
- Livestock farms, wild animals, or others which are likely to cause disturbances.

Source: Ministerial Regulation, No. 116 (1992), MOI.

Appendix 6.9 A program for computation of volume of land fill in the Klong Toei project.



```

$ EDIT RUN1.FOR          <RETURN>
*C                        <RETURN>
C  THE RAW HEIGHT DATA DERIVED FROM AP190 FOR LAND FILLING

CHARACTER*20 INTF

INTEGER I
REAL Z(5000),C(5000), C1, HEIGHT, BASE, WIDTH
REAL SUM0, SUM1, SUM2, SUM3, AREA, VOLUME

WRITE(6,*) 'Input a file name (with extension).'
READ(5,10) INTF
10  FORMAT(A60)

OPEN(3, FILE=INTF, STATUS='OLD')

WRITE (6,*) 'HEIGHT (Three decimals are needed.)'
READ (5,*) HEIGHT
WRITE (6,*) 'BASE (Three decimals are needed.)'
READ (5,*) BASE
WRITE (6,*) 'WIDTH (Three decimals are needed.)'

```

```

      READ (5,*) WIDTH

      NPTS = 0
20  READ(3,*,END=30) A1, B1, C1
      NPTS = NPTS + 1
      C(NPTS) = C1
      Z(NPTS) = HEIGHT - C(NPTS)
      GOTO 20
30  WRITE (6,*) 'Total number of points =', NPTS

      SUM0 = 0.0
      DO 40 I = 2, NPTS - 1
      SUM0 = SUM0 + Z(I)
40  CONTINUE

      SUM1 = Z(1) + Z(NPTS)
      SUM2 = ((2.00 * SUM0) + SUM1)
      SUM3 = SUM2 * BASE
      AREA = SUM3 / 2.00
      VOLUME = WIDTH * AREA

      PRINT *, ''
      PRINT *, ''
      PRINT *, '-----'
      PRINT *, 'Total cubic metres of the land-filled area =', VOLUME
      PRINT *, '-----'

      STOP
      END

```

```

[CTRL] [Z]
*EX

```

```

$ FORTRAN RUN1.FOR      <RETURN>
$ LINK RUN1             <RETURN>
$ RUN RUN1              <RETURN>
Input a file name (with extention).
TOTDTM.PTS             <RETURN>
HEIGHT (Three decimals are needed.)
1.500                  <RETURN>
BASE (Three decimals are needed.)
20.000                 <RETURN>
WIDTH (Three decimals are needed.)
20.000                 <RETURN>
Total number of points =      2540

```

```

-----
Total cubic metres of the land-filled area =  1042925.
-----

```

```

FORTRAN STOP
$ LOG OFF

```

THE USE OF PHOTOGRAMMETRIC AND GPS TECHNIQUES FOR DIGITAL MAPPING OF LAND READJUSTMENT IN THAILAND

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Abstract

The existing urban and suburban cadastral maps in developing countries are often out-of-date, cluttered in detail, incomplete, or at too small a scale. The problem is particularly critical in Bangkok, Thailand, where the rapid urban growth rate means that maps are soon in need of revision. Moreover, most of the suburban areas are still lacking any cadastral maps. Such maps are deemed to be a fundamental requirement for city planners whenever land readjustment is being implemented. As a consequence the utilisation of up-to-date large scale aerial photographs, GPS, and an economical analytical stereoplotter are being applied to help meet the requirement of city planners. The Trimble 4000ST GPS equipment has been used, in its differential mode, to establish three-dimensional ground control points to within centimetres. On the AP190 analytical photogrammetric stereodigitiser, a block aerotriangulation package has been used to densify the minor control points. These points will be used later in the process of digital cadastral mapping for urban and suburban areas in Bangkok.

1. INTRODUCTION

The population of Bangkok, Thailand, is over 8.5 million, which places it among the most populated cities of the developing world. Recent economic expansion has been rapid, bringing with it pressures on urban land use and a concurrent rapid rise in market land prices which exceeds income and productivity growth. In early 1991, a World Bank Consultant Mission visited the National Housing Authority (NHA) to draft the framework for an experiment project on land readjustment in Bangkok (National Housing Authority, 1991). Based on the

experience of other countries (e.g. Germany, Japan, South Korea, Taiwan), it is no accident that land readjustment can have a potentially significant impact on the availability of urban land in Bangkok and provincial cities of Thailand. The existing urban and suburban large-scale base maps, for instance cadastral maps and land use maps in the Third World countries, are obsolete and incomplete. The problem is evident in many government organisations which are responsible for city planning in Bangkok, where the rapid urban growth rate means that maps are soon in need of revision. The maps are considered to play a vital role for city planners whenever land readjustment is taking place.

Consequently, as examples of the types of area dealt with by city planners, two study areas were selected within Bangkok Metropolitan General Plan Area: an urbanised area and a suburban area. The urbanised area covers approximately 0.5 square kilometres in Klong Toei District. This is considered to be a densely urbanised area. Therefore, the treatment will be mainly focused on the digital mapping of buildings. The suburban area covers approximately one square kilometre located in Lad Krabang District. The typical existing suburban land parcel in this area is long and thin, sometimes 600 metres long and as narrow as 40 metres. Accessibility is usually by canals running perpendicular to the parcels and by roads. For the suburban area, the treatment will be directed to digital land value mapping.

2. METHODOLOGY

The applications of photogrammetric, GPS, and land information system techniques to produce various digital maps were performed in successive steps as follows:

2.1 Aerial photographs acquisition

Panchromatic aerial photographs (paper print type) at a scale of 1:6000 were used as a source of data for both study areas; the photographs were taken by normal-angle-lens metric cameras, with forward overlap 60 %, and sidelap 25 %.

2.2 Survey control data for aerial triangulation

For horizontal control points, the Royal Thai Survey Department (RTSD) kindly provided a first order horizontal control point (RS29) which is based on the Universal Transverse Mercator (UTM) Projection, derived from geographical coordinates based on the Indian Datum as readjusted in 1975. The control point is about 15 kilometres southeast of the Lad Krabang project. The point was transformed to the World Geodetic System 1984 (WGS84) and afterward was then used in TRIMVEC software as a reference location for coordinate adjustment.

For vertical control points, the first class levelling survey routes adjacent to the study area in the Lad Krabang District were established in the project described by RTSD in 1981 (North West-Stewart Weir Group, 1987). For the research, the RTSD provided two of the first order levelling points, BMS 9205-2/32 and BMP 470. The first is about 3 kilometres northeast and the second is about 15 kilometres southeast of the Lad Krabang project.

2.3 Field work preparation

A city map at a scale of 1:4000 (Series 9013 S-04, sheet 11-3-D) is available only in the densely urbanised area. General purpose maps at a scale of 1:10000 (Series 9013 S-1, Sheet 11-3, 12-1, and 12-3) cover the whole of Bangkok Metropolitan Area. They have been introduced to aid in field work preparation, for example, in photo indexing, allocation of ground control points for a GPS, and designation of vertical and horizontal points for aerial triangulation.

An uncontrolled mosaic of aerial photographs in the Lad Krabang District was utilised for planning of ground control and minor control points in the aerial triangulation process.

2.4 Reconnaissance

A reconnaissance was undertaken in the Lad Krabang project. Four full ground control points were located in the perimeter and a fifth point was located approximately in the middle of the survey area. In addition, ten vertical control points were designated along the survey routes. The reason for the number and distribution of control points was in order to enhance a rigorous independent model block adjustment.

A reconnaissance in the Klong Toei project revealed that there was heavy vehicular traffic and great difficulty of finding suitable sites at ground level for survey control markers that were safe from interference. Moreover, high-rise buildings are a hindrance to monitoring GPS observations. Consequently, it was decided to make use of reliable horizontal coordinates from the Department of Lands (DOL) which were adjusted in UTM system by means of an independent model block adjustment program (PAT-M43) carried out in 1989.

2.5 Mensuration by GPS

The Trimble 4000ST GPS SURVEYOR is designed for high-precision survey applications. When used with TRIMVEC PLUSTM suite of software, three-dimensional coordinate differences between stations can be determined. The 4000ST receives L1 signal (1574.42 MHz) sent from the Global Positioning System NAVSTAR (Navigation Satellite Timing and Ranging) satellites. Three identical Trimble 4000ST GPS SURVEYOR receivers were used to undertake static and differential surveys in the Lad Krabang project.

Of the four different methods of using the GPS equipment (Trimble Navigation, Ltd., 1991): the pre-planned survey method together with 'once at specified date and time' mode was chosen for the treatment because this method has the advantage of being pre-programmed into the 4000ST, either from a computer or the 4000ST front panel, prior to running the survey. Consequently, the basic steps required to schedule a survey into the 4000ST were station-ID, session, and survey start and stop time as shown in Table 1. For instance, the three identical Trimble 4000ST receivers (GPS I, GPS II, GPS III) were set over designated points DC11, DC12 and DC13 successively by the day-of-the-year or Julian day, a digit indicating the run sequence (318-1, 318-2, and so forth) at 0800-1000 a.m.

Figure 1 shows the relationship between the six GPS stations. The logistics of the field operation involved three trained assistants, three labouring assistants, two cars and three walkie-talkie receivers. The known coordinate point (RS29), which

was transformed to WGS84, was introduced into the microcomputer during processing to compute accurate coordinates of the five unknown points (DC11, DC12, DC13, DC14, and DC15).

2.6 Heighting

A vertical control survey for photogrammetric purposes was required for all the designated points in the Lad Krabang project. All elevations were referred to Bench Mark 9205-2/32 (elev. 1.0524 m, 1989). In addition, an elevation of the first order horizontal control point (RS29) was also referred to Bench Mark 470 (elev. 1.6760 m, 1989). Both of these are located in Wat Rajkosa, Lad Krabang District, Bangkok. The vertical survey was completed by levelling, using a Wild NK2 level.

2.7 Digital mapping

A provisional digital map was produced by means of control points derived by the aerial triangulation method. The map was produced by using aerial photographs (paper print type) in an analytical stereoplotter Wild BC1 in the Department of Survey Engineering, Chulalongkorn University, Bangkok, Thailand. Viewing in three dimensions was rather poor since the stereoplotter was designed to cope normally with diapositives. The provisional cadastral map represented 28 parcels of land in the Lad Krabang project at a scale of 1:4000.

In the Klong Toei project, a digital cadastral map and a building map were provided by the Bangkok Metropolitan Administration (BMA), both at 1:4000 scale. It was obvious that there were some mistakes in the building map, for example, irregular shapes of the buildings. Therefore, it was decided that the digital building map and the land value map would have to be replotted. This will be done at the Department of Geography, University of Edinburgh, using an AP190 analytical stereodigitiser and the ARC/INFO utilities.

In the Lad Krabang project, the photo-controlled points derived by means of aerial triangulation using a block adjustment program. In the Klong Toei project, the stereomodel was created using four of rigorous horizontal control points provided by the DOL, Thailand.

The exploitation of aerial triangulation is to determine the absolute orientation of many models simultaneously. The models are linked together using tie points, and the block is transformed to the ground coordinate system through the control points. In the research, there were 3 strips of stereomodels; each strip was composed of 5 stereomodels. The independent model block was controlled by 5 full ground and 10 vertical control points. The block was carried out using the BLOKK program, version 7.0, which was developed by Carto Instruments, Norway. Like other well-known programs, the BLOKK program also provides choices, namely, adjustment of planimetry, adjustment of height, adjustment of three dimension (or planimetry and height). Above all, the program runs on microcomputer, IBM AT or compatible and the input is data collected with the AP190 analytical stereoplotter which is already available in the Department of Geography, University of Edinburgh.

2.8 Field completion

In the Lad Krabang project, the provisional cadastral map and aerial photos at a scale of 1:6000 were used for field completion. There were some mistakes related to parcel shape in the map because of misinterpretation during plotting. There was also a minor change because four houses were physically removed to be rebuilt outside of the Lad Krabang project area. As most of the land parcels are swamp or deserted rice fields, and the way of life of residents is still confined to agriculture activities, there have been no changes in the land use since 1988. In addition, it was determined that the electricity network is the only network which has recently been installed. This network is located along the Lum Nai So canal which is perpendicular to the northern part of the study area.

In the Klong Toei project, the cadastral map, the building map (sponsored by BMA) and the aerial photos at a scale of 1:6000 were used extensively for field completion. The DOL is normally responsible for the cadastral map. Therefore, it had to be assumed that the cadastral map was up-to-date and did not require revision since there was no more up-to-date land evidence from the DOL. In the period between the taking of the photographs and the photo-interpretation, there had also been some building changes; some property ownership boundaries were also altered. There had been some changes in land use due to a tremendous increase in demand for housing since 1986 (e.g. altering vacant areas to residential areas). Moreover, existing buildings were renovated in order to change the way they were used (e.g. converting detached houses into commercial firms without demolishing and rebuilding). Networks of public utilities (e.g. electricity, telephone, water supply) are installed throughout the area, but unfortunately the documents describing most types of public utility are not available to the public. In consequence, positions of public utilities like electric poles, water hydrants and manholes, have to be extracted from the 1:6000 scale aerial photographs.

2.9 Land use classification

In a part of the project which is not yet completed, a land use classification and a building type classification will be produced. The land use classification will be adapted from a standard land use classification of Mapping Division, Department of Town and Country Planning (DTCP), Thailand (e.g. residential, commercial, etc).

Building type will also be adapted from a standard of Building Assets Assessment List (1992), Assets Assessment Committee, Ministry of Interior, Thailand. The list will play a vital role in computing cost of building removal in land readjustment procedure (e.g. detached house, bungalow, town house, etc).

3. RESULTS

3.1 Elevation computation

The results of the heighting in the Lad Krabang project were achieved to Thailand's third order level specifications ($12\text{ K}^{1/2}\text{ mm}$) which were accurate enough for observation in GPS and in the process of aerial triangulation.

3.2 Processing GPS survey data

Processing the GPS survey data requires the use of the TRIMVEC PLUS postprocessing software and a computer with 640 KB of RAM and a math co-processor chip. In the research, a microcomputer with a hard disk was utilised. The process involved downloading the GPS survey data from the three receivers and using the Automatic Processing option, after which the downloading data would be computed and adjusted as shown in Table 2 and Table 3.

There was no doubt about the precision of the XY results from GPS, which matched its first-order specification. An interesting difference in GPS measurements resulted from the 15 kilometres distance between the reference station RS29 and the five stations in the Lad Krabang area (Figure 1). When the coordinates of station RS29 were fixed in XYZ, the results in height of the five unknown stations (DC11-15) differed from their heights derived from field levelling by a mean of approx. -70 cm (Table 2). In contrast when station RS29 was fixed in XY only and one of the stations (DC11) was fixed in Z (Table 3), the height errors of the five stations were consistent to a few centimetres with a +70 cm error at RS29. Table 4 illustrates the combined effect of the geographical spacing between the reference station and the field area.

The explanation for the height errors relates to the figure of the Earth. The ellipsoid used internally in the 4000ST is that developed from the WGS84. The WGS84 ellipsoid is a smooth, mathematically convenient surface which facilitates the representation of latitude, longitude and altitude within the 4000ST receiver. The ellipsoid is only an approximation to the surface of the Earth. At the same time, the geoid is based on the gravity equipotential surface, and the geoid accurately models mean sea level (MSL) around the globe (Magellan Systems Corporation, 1991). Since altitudes on maps are almost always relative to sea level, the altitude presented on Figure 2 is the height above MSL, which is the same height above the geoid. Therefore, after introduction of a mean Earth ellipsoid (WGS84), the coordinate differences Northing and Easting are perfectly well suited to locate the points (DC11, DC12, DC13, DC14, and DC15) on the ellipsoid, but the heights have a severe shortcoming. According to Table 4, GPS or geometric height differences (Δh) caused by geoid height differences (ΔN) are approximately 70 centimetres. Consequently, the adjusted height at the points (DC11, DC12, DC13, DC14, and DC15) will be corrected by adding 69 centimetres in height to the point RS29. By this method, the height at point RS29 is now equal to 1.27 m. After re-running the program, the heights of all points were very similar to the height derived by ground survey.

3.3 Aerial triangulation (independent model block adjustment)

The input required 15 model coordinates and the output were the ground XYZ coordinate values of 17 tie points and 27 pass points, which were then used as control points for absolute orientation of the models. Sigma naught (σ_0) values which represent the standard error of the adjusted coordinates are indicated in Table 5.

3.4 Digital mapping

The potential of the AP190 analytical stereodigitiser as a spatial data capture for land readjustment has been shown to be very good. After the orientations are properly performed, a stereoscopic model can be digitised directly to produce an accurate and reliable map. For this paper, two set of ASCII files created by the AP190 were sent to ARC/INFO version 6.1. From this GIS package, a digital map of buildings (Figure 3) and a land value map (Figure 4) were generated.

4. CONCLUSION

A set of three identical Trimble 4000ST GPS receivers with TRIMVEC PLUSTM suite of software were employed to generate ground control points which were later applied in an independent model block adjustment program. Following this, an AP190 analytical stereoscopic plotter was utilised for collecting digital data from stereoscopic models with well-controlled minor control points. It is evident that the available technologies, for example, GPS and the AP190, are not difficult to operate and require less effort than traditional field survey methods. The GPS can also be observed in nearly all weather conditions. The AP190 has a high performance and can be considered to be an economical analytical stereodigitiser. Moreover, with the help of ARC/INFO, it was straightforward to produce a digital building map and a land value map as a source of spatial data for land readjustment. It is suggested that these techniques could be adopted in urban mapping for land readjustment in many developing countries.

5. REFERENCES

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Table 1. Pre-planned survey

	GPS I	GPS II	GPS III	SESSION	TIME
STATION-ID	DC11	DC12	DC13	318-1	0800-1000
STATION-ID	DC11	DC14	DC13	318-2	1030-1230
STATION-ID	DC12	DC14	DC15	318-3	1300-1500
STATION-ID	DC12	DC14	RS29	318-4	1600-1800

Table 2. Summary of coordinate adjustment (fixed XYZ at point RS29).

Pt #	STATION-ID	NORTHING (m)	EASTING (m)	HEIGHT (m)	FIXED	KNOWN
1	DC11	1521078.8263	684797.0400	4.47	-----	YXZ
2	DC12	1523542.7529	684717.4213	1.33	-----	YXZ
3	DC13	1523034.4098	687598.6011	-0.11	-----	YXZ
4	DC14	1521606.4189	687478.7006	-0.53	-----	YXZ
5	DC15	1522815.1626	686393.9545	0.89	-----	YXZ
6	RS29	1515060.8040	700606.4480	0.58	-----	YXZ

Table 3. Summary of coordinate adjustment (fixed XY at point RS29 and fixed Z at point DC11).

Pt#	STATION-ID	NORTHING (m)	EASTING (m)	HEIGHT (m)	FIXED	KNOWN
1	DC11	1521078.8263	684797.0400	5.16	-Z	YXZ
2	DC12	1523542.7529	684717.4213	2.02	-----	YXZ
3	DC13	1523034.4098	687598.6011	0.58	-----	YXZ
4	DC14	1521606.4189	686478.7006	0.15	-----	YXZ
5	DC15	1522815.1626	686393.9545	1.58	-----	YXZ
6	RS29	1515060.8040	700606.4480	1.27	YX-	YXZ

Table 4. Differences in height between ground control survey and GPS.

STATION-ID	GROUND CONTROL (m)	GPS (m)		DIFFERENCE (m)	
		FIXED RS29	FIXED DC11	RS29	DC11
DC11	5.16	4.47	5.16	-0.69	0.00
DC12	2.08	1.33	2.02	-0.75	-0.06
DC13	0.53	-0.11	0.58	-0.64	0.05
DC14	0.10	-0.53	0.15	-0.63	0.05
DC15	1.58	0.89	1.58	-0.69	0.00
RS29	0.58	0.58	1.27	0.00	0.69

Table 5. Results of independent model block adjustment by using BLOKK.

INDEPENDENT MODEL BLOCK ADJUSTMENT	SIGMA NAUGHT (m unit in terrain)
PLANIMETRY	0.42
HEIGHT	0.50
PLANIMETRY and HEIGHT	0.42

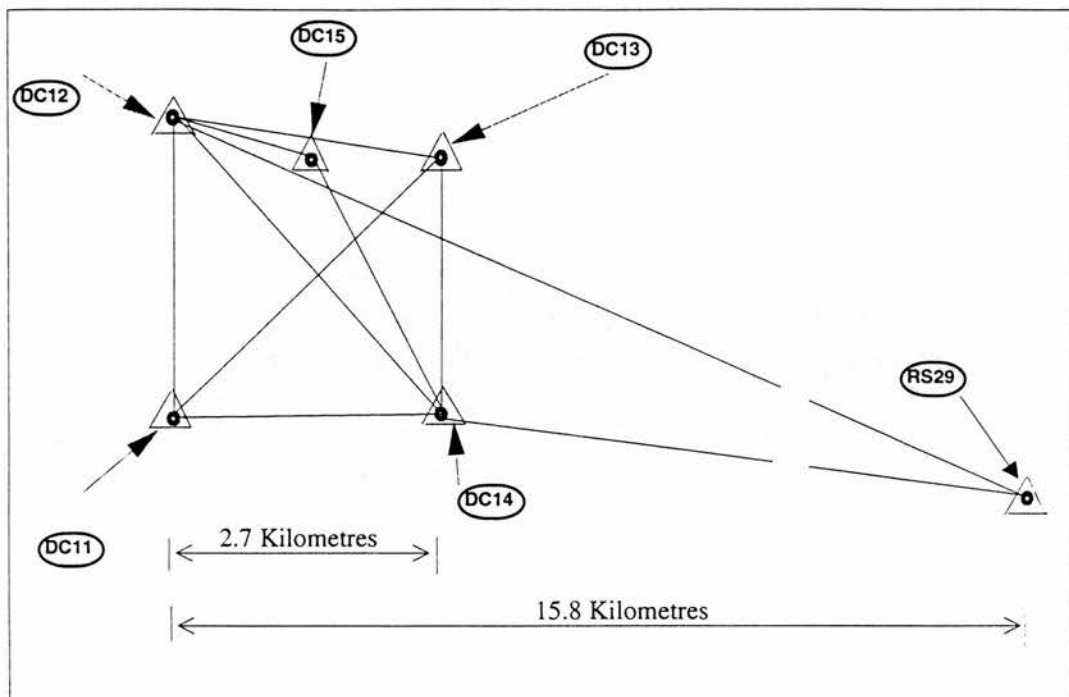


Figure 1 GPS network in the Lad Krabang project.

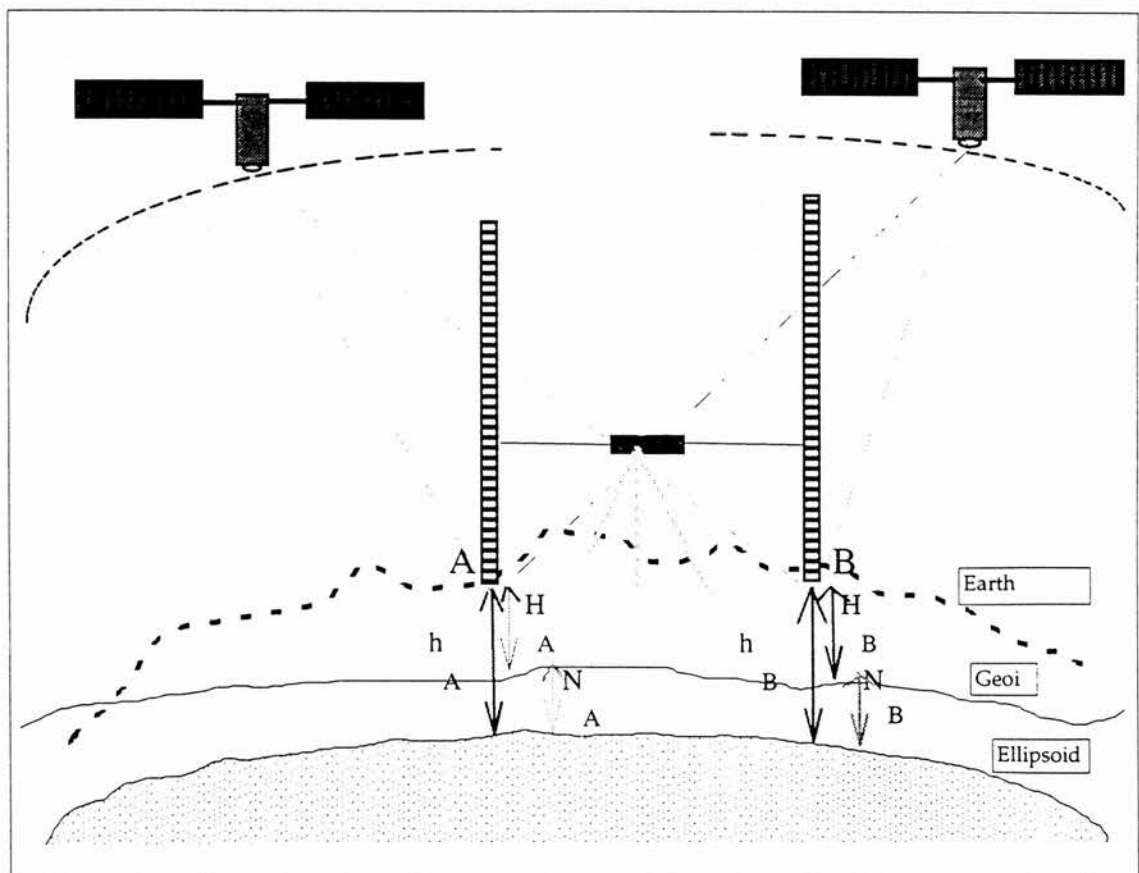


Figure 2 Levelling by GPS.

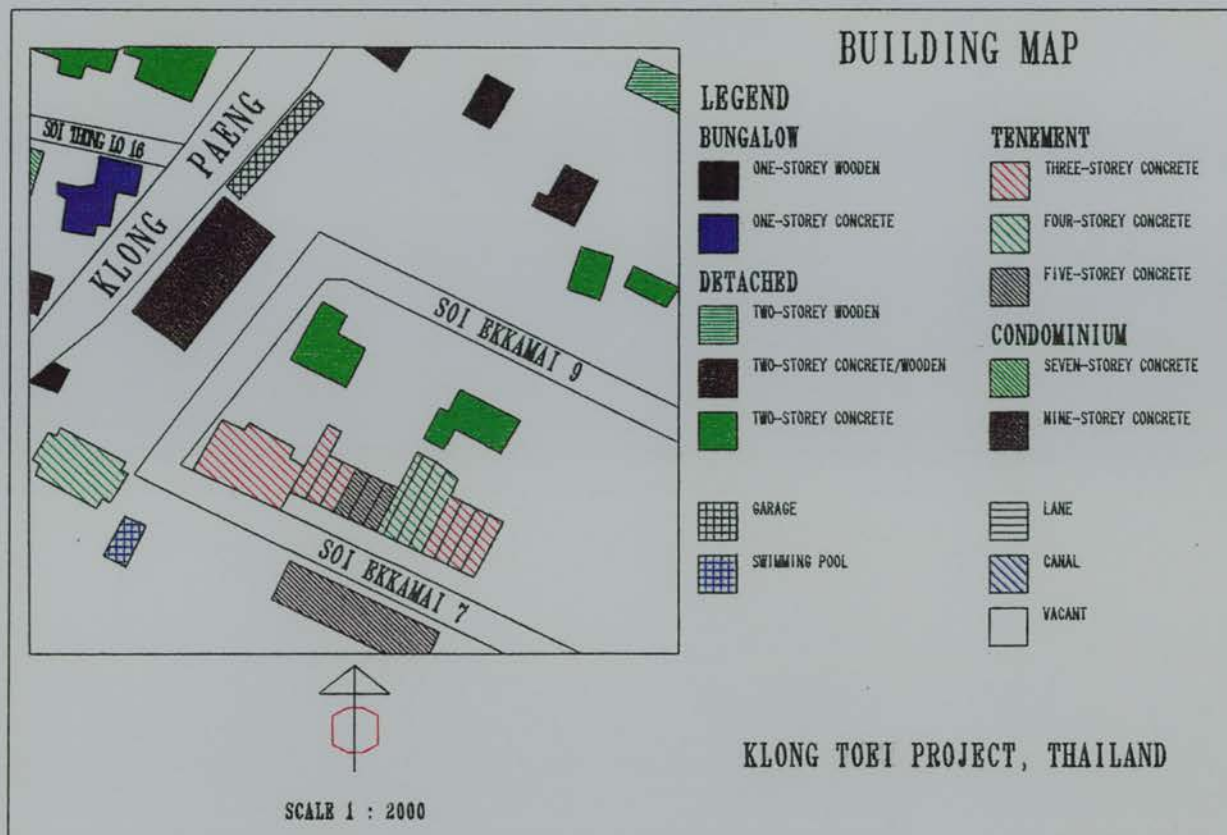


Figure 3. Building map in Klong Toei project, Bangkok, Thailand.

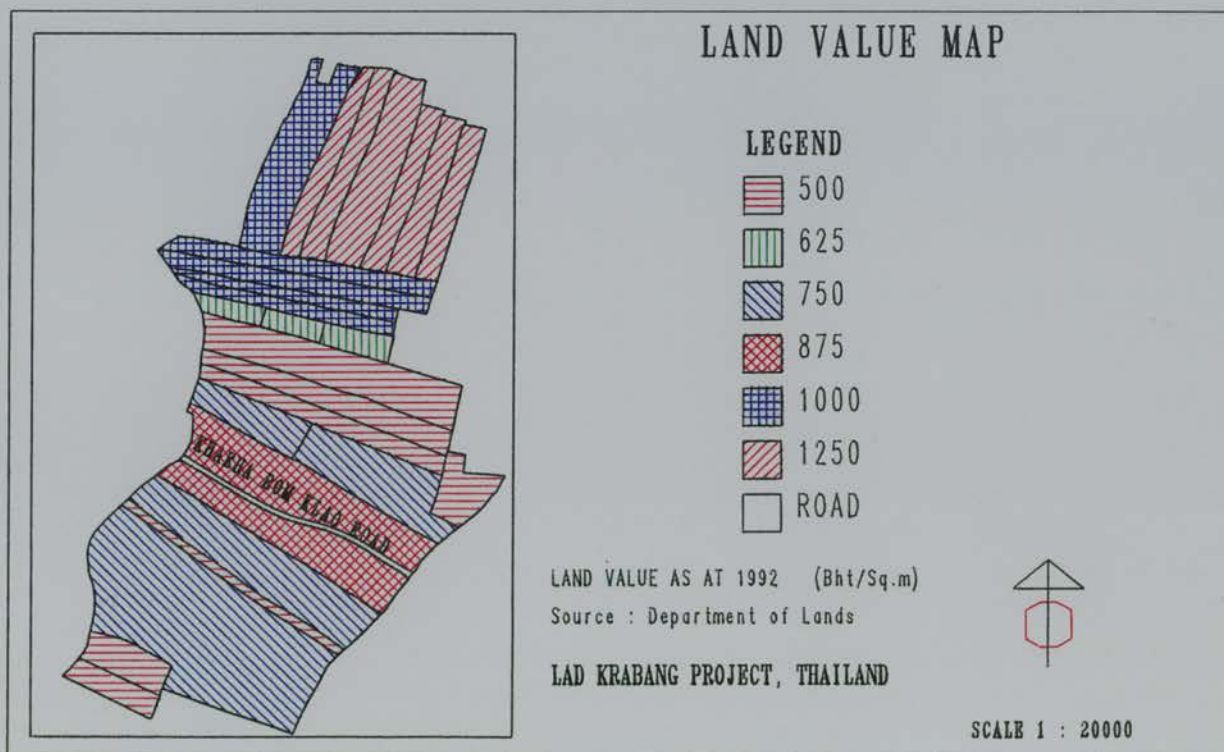


Figure 4. Land value map in Lad Krabang project, Bangkok, Thailand.

URBAN AND SUBURBAN MAPPING WITH THE AP190 ANALYTICAL PLOTTER

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(Paper read at the Thompson Symposium held at the University of York on 10th April, 1994)

Abstract

The AP190 analytical stereoplotter has been employed for two research projects concerned with the urban and suburban environment. In the first project, the suitability of the AP190 was assessed for comparing height readings between stereomodels of colour diapositives and colour paper prints, for collecting height data for a digital terrain model and for producing a land use map using a stereopair of part of Edinburgh under well controlled conditions. The second project dealt with the densification of minor control points by means of the BLOKK aerial triangulation package, followed by the digital mapping of a suburban area planned for land readjustment in Bangkok.

INTRODUCTION

ANALYTICAL STEREOPLOTTERS using sophisticated software are now the industry standard. All PC-based analytical stereoplotters (such as the Zeiss Planicomp P3 and Leica SD2000) are capable of making three dimensional measurements directly from aerial photographs but they vary in their accuracy and ease of use. The Carto Instruments AP190 analytical stereoplotter permits derivation of special functions such as line length, area, height, slope and azimuth and it allows digitization directly into any CAD or GIS system. Alternatively, the data can be stored in the PC and later easily transferred (in an ASCII format) to an information system for spatial analysis or to a plotter for generating maps (Warner and Carson, 1990).

In this paper, the use of the AP190 is described for separate research projects in the urban and suburban environment in different countries. For the urban area of Holyrood, Edinburgh, the aim was to compare the accuracy of height readings from two different media (colour diapositives and colour paper prints). The AP190 was also used for collecting height data for use in a ARC/TIN program, and for producing a digital land use map. In addition, for the suburban area in Bangkok, Thailand, the AP190 has been used for the densification of minor control points by using an aerial triangulation package, BLOKK, followed by digital mapping.

AN APPLICATION OF THE AP190 IN AN URBAN ENVIRONMENT

Ground Surveying

The northern part of the Holyrood district was chosen as a test model for evaluation of the AP190 because it contains a good representative selection of landforms within the city, varying from hilly to flat terrain. Colour diapositives and colour paper prints at 1:5000 scale, taken by a normal angle camera fitted with forward motion compensation (FMC), were used for height mensuration, for collecting height data for a digital terrain model (DTM) and for generating a digital land use map. A total of five horizontal and 35 vertical control points were established; they were all natural points

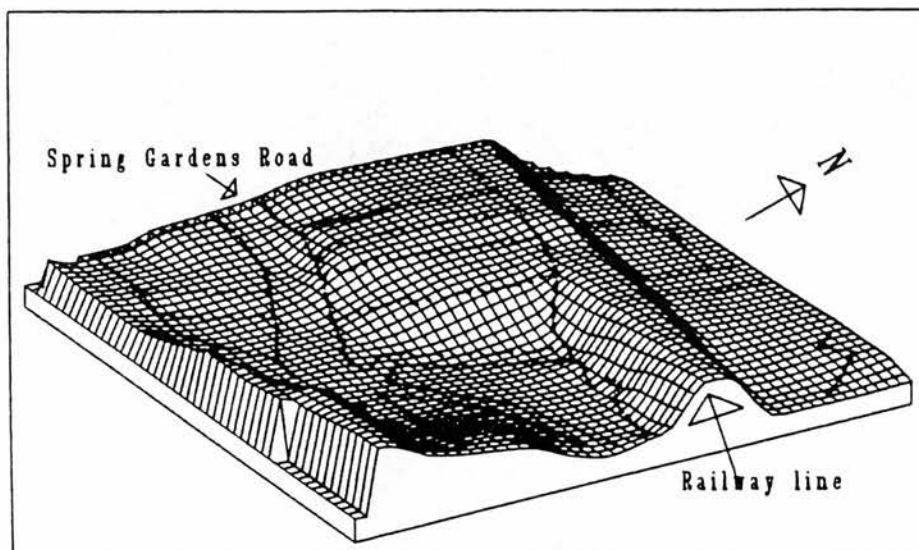


FIG. 1. A perspective view of the Holyrood district, Edinburgh. Vertical exaggeration is $\times 12$.

and clearly identifiable on the colour diapositives and colour paper prints. A closed traverse of the five ground control points was observed to fulfil the requirement of horizontal photocontrol points and the heights of 35 vertical control points were determined by levelling.

Heighting Accuracy Test of AP190

A comparison of height readings between a stereomodel of colour diapositives and a stereomodel of colour paper prints was made. The stereomodels were well controlled by five points in X , Y , Z and six points in Z only. The height testing was carried out using a set of 24 well distributed points in the stereomodels. A total of five repetitions of the height measurements was made for each set of 24 points for both diapositive and paper print models. The accuracy of overall test points is shown in Table I under the headings of S.D. (standard deviation) and r.m.s.e.

TABLE I. Height accuracy using the AP190.

Type of aerial photographs	S.D. (m) Z	r.m.s.e. (m) Z
Colour diapositive	0.09	0.16
Colour paper print	0.10	0.25

Height Data for Triangulated Irregular Network (TIN) Program

A photogrammetric approach can help meet the requirements of city planners for obtaining a DTM in urbanized areas. The stereodigitizing was made by digitizing in the spaces between buildings and where sightings are not obscured by trees. Using a pair of colour diapositives, heights were obtained in point mode with fixed increments of 1 m interval. The digitizing was performed as a combination of the fixed increment operation with additional feature-specific (F-S) data (a total of 679 points). After digitizing, all data which contained X , Y , and Z values (as real numbers) were sent to Geovax in ASCII format. By means of a small Fortran program, the Z values were changed to integers which are then executed as a field of User-ID in ARC/INFO

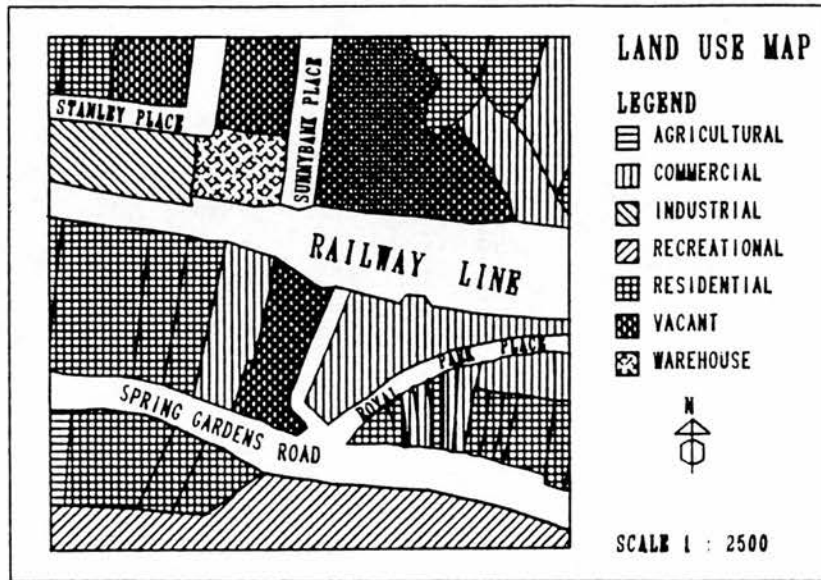


Fig. 2. A land use map of the Holyrood district, Edinburgh.

(Chanlikit, 1991). With the help of the ARC/TIN utility, a three dimensional model was generated (Fig. 1).

Digital Land Use Map

For the same Holyrood district, the stereomodel of colour diapositives was digitized in line mode by means of the AP190. After digitizing, field completion was carried out for land use classification. With the help of ARC/INFO, a land use map was produced (Fig. 2).

AN APPLICATION OF THE AP190 IN A SUBURBAN ENVIRONMENT

GPS and Heighting

Most suburban areas in the developing countries still lack any cadastral maps. Such maps are regarded as a rudimentary requirement for city planners whenever land readjustment is being implemented. The current methods based on ground survey are slow and labour intensive. Consequently, an alternative scheme involving up to date large scale aerial photographs, GPS and an analytical stereoplotter has been developed, which it is hoped can better fulfil the need of city planners. The scheme was developed for a test site in the suburban area of Lad Krabang district, Bangkok. Three identical Trimble 4000ST GPS receivers were used to undertake static and differential surveys at five unknown points and one known point. The basic steps required to schedule a survey into the 4000ST were station-ID, session, and survey start and stop time (Chanlikit and Kirby, 1993). One known co-ordinated point, which was transformed to WGS84, was introduced into the microcomputer during processing to compute accurate co-ordinates of the five unknown points. In addition, 16 vertical control points were established by levelling.

Independent Model Block Adjustment

Panchromatic aerial photographs (paper prints) at a scale of 1:6000, taken with a normal angle metric camera, were employed for testing an independent model block

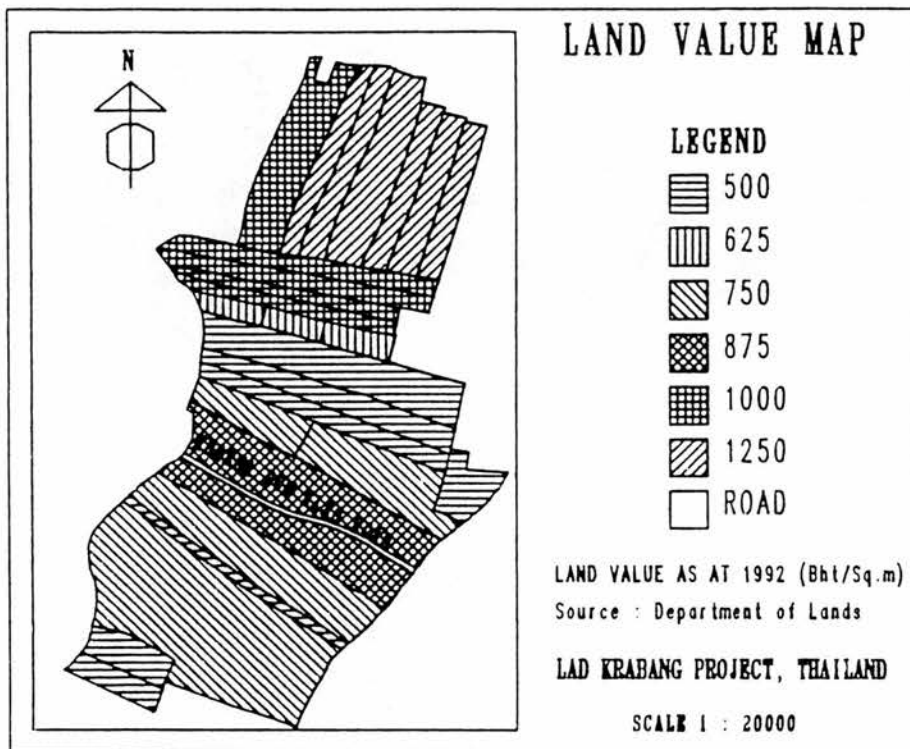


FIG. 3. A land value map of part of Lad Krabang district, Bangkok.

program (BLOKK), which was developed by Carto Instruments, Norway. The block consisted of three strips of stereomodels, each strip containing five models. An independent model block of the 15 models was observed on the AP190. The models were linked together using tie points and the block was transformed to the ground co-ordinate system through the control points by means of the BLOKK program. The input required 15 model co-ordinates and the output consisted of the terrain co-ordinates of the pass and tie points, which were then used as control points for absolute orientation of the models.

Digital Land Value Map

Five stereomodels, which were controlled by the adjusted co-ordinates derived from the independent model block adjustment, were digitized by the AP190 in line mode and sent to ARC/INFO. From this GIS package, a digital map of land value in Lad Krabang district was generated (Fig. 3).

CONCLUSION

In this study, the capabilities of the AP190 for height mensuration, digital mapping and densification of minor control points were assessed. To assess the precision of the AP190 as a tool for spatial data capture for urban mapping, for the Holyrood district, Edinburgh, accurate ground control data from field survey were acquired for orientations, following which the height readings were investigated with good results. A set of height data was used via ARC/TIN to generate the digital terrain model; in addition, a land use map was produced by using ARC/INFO.

In the case of suburban mapping for land readjustment in Thailand, with the help

of GPS and the BLOKK program, it is evident that a photogrammetric approach requires less effort than conventional field survey methods. In relation to equipment, it is suggested that the AP190 has a high performance and can be deemed to be reliable and economic compared to other instruments which are currently available.

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Résumé

On a mis en œuvre le restituteur analytique AP 190 dans deux actions de recherche liées aux milieux urbain et sub-urbain. Dans la première, on a utilisé et testé la possibilité de l'AP 190 pour comparer les mesures altimétriques entre stéréomodèles formés de diapositives-couleur et de tirages-couleur sur papier, pour obtenir les données altimétriques nécessaires à l'établissement d'un modèle numérique du terrain et pour établir une carte d'usage des sols à partir d'un couple stéréoscopique d'une partie d'Edimbourg, appuyé sur un canevas normal. La seconde action de recherche visait à densifier le réseau de points d'appui en utilisant l'ensemble des logiciels BLOKK d'aérottriangulation, et à réaliser ensuite une carte numérique dans une région sub-urbaine de Bangkok, sujette à un ré-aménagement.

Zusammenfassung

Das analytische Auswertegerät AP 190 wurde für 2 Forschungsprojekte, die sich mit der städtischen und vorstädtischen Umwelt befaßten, verwendet. Beim 1. Projekt wurde die Eignung des Gerätes getestet, indem vergleichsweise Höhenmessungen in Stereomodellen auf der Grundlage von Farbdia-positiven und Farbpapierbildern für die Gewinnung von Höhendaten für ein digitales Geländemodell und zur Herstellung einer Landnutzungskarte auf der Grundlage eines Bildpaars eines Gebiets von Edinburgh unter gut gesteuerten Bedingungen erfolgten. Das 2. Projekt befaßte sich mit der Paßpunktverdichtung mit Hilfe des Programmpaketes BLOKK zur Aerotriangulation. Dem schloß sich die digitale Kartenherstellung eines Vorstadt-gebietes von Bangkok an, für das eine Landneuordnung geplant ist.